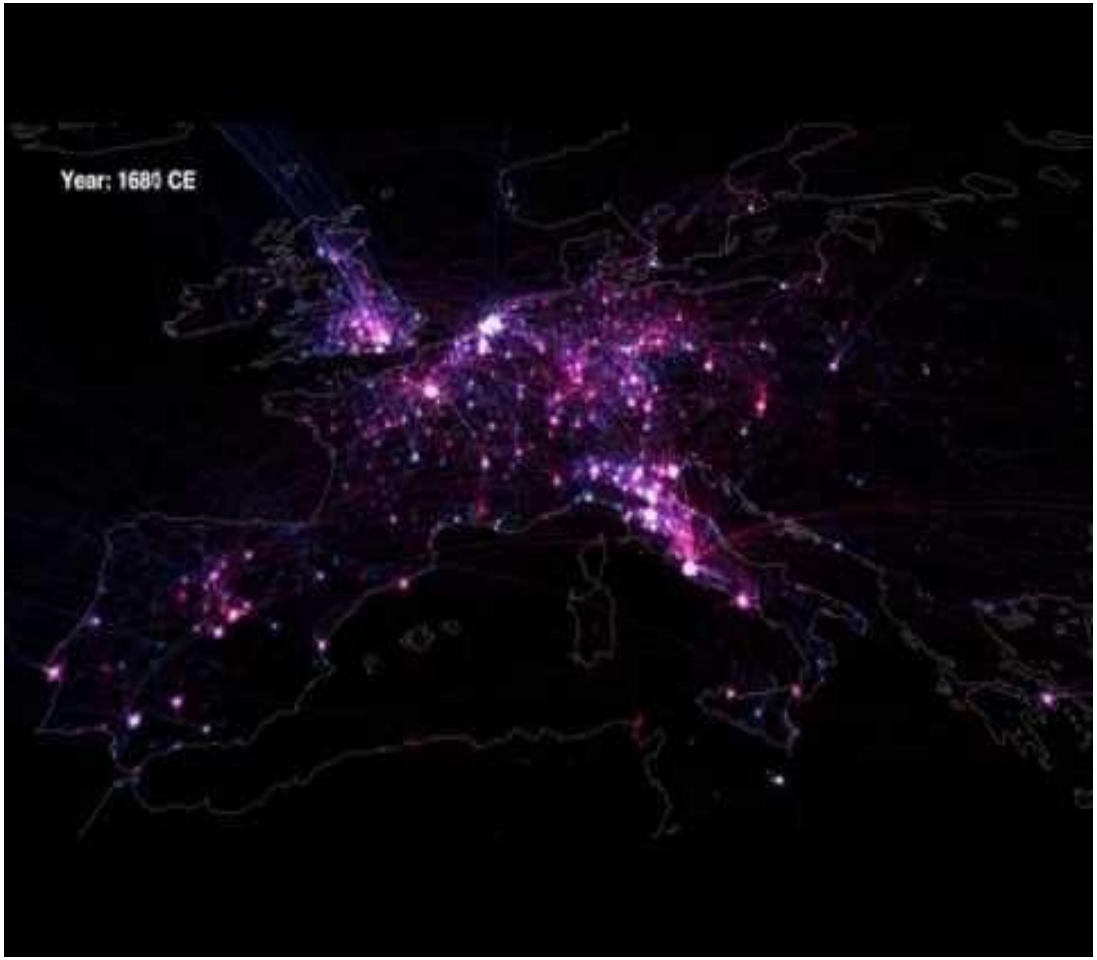
Toyota GCP Workshop, Jan 15 - 16, 2015

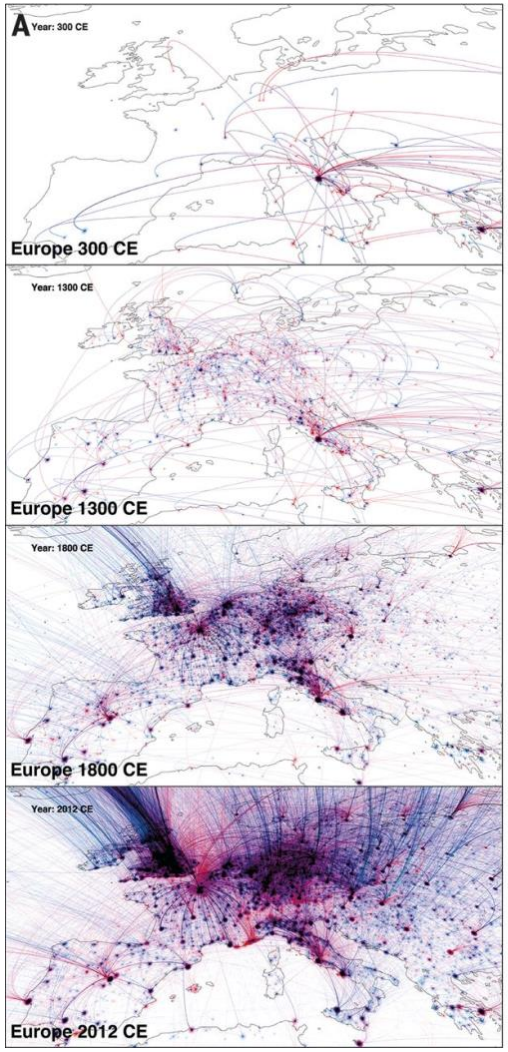
Land use scenarios: Trade-offs between benefits and risks

Yoshiki Yamagata and Daisuke Murakami

Center for Global Environmental Research,
National Institute for Environmental Studies, Japan

European birth to death network dynamics



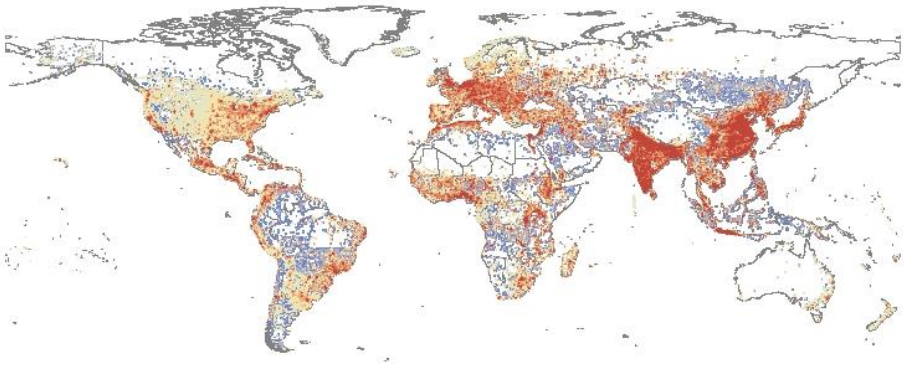


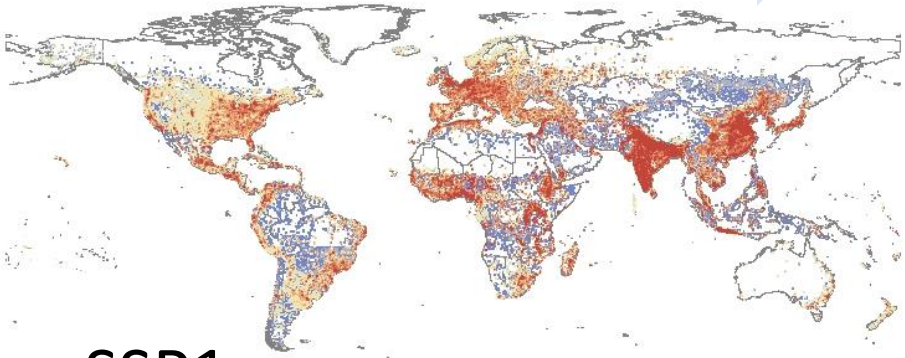
Birth and death location data of 120,211 notable individuals

Source: Schich (2014) A network framework of cultural history. Science

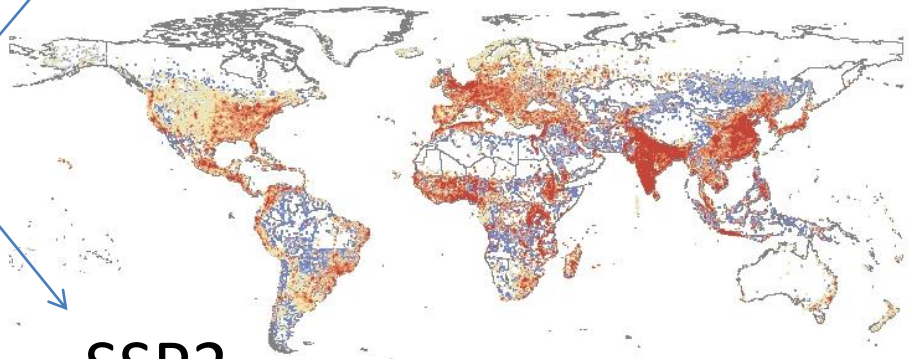
Population in the future

2000 → 2080

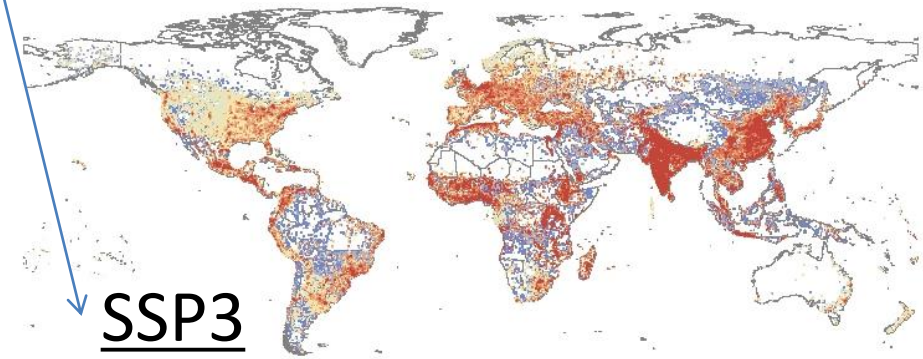




SSP1



SSP2



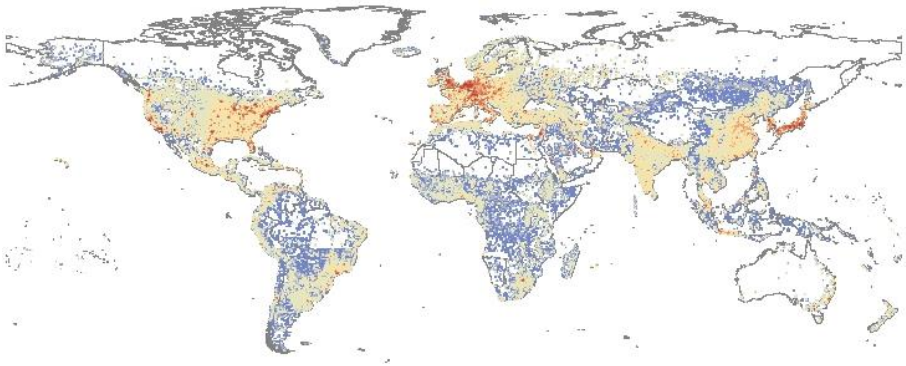
SSP3

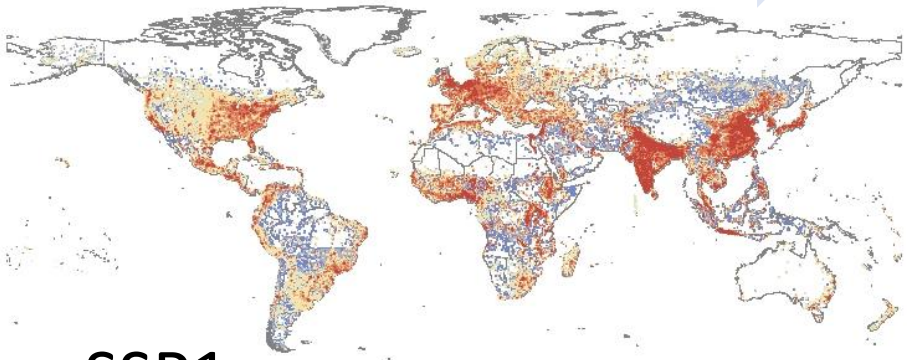
Future transport network innovation scenarios are to be developed

(Murakami and Yamagata 2014, in prep.)

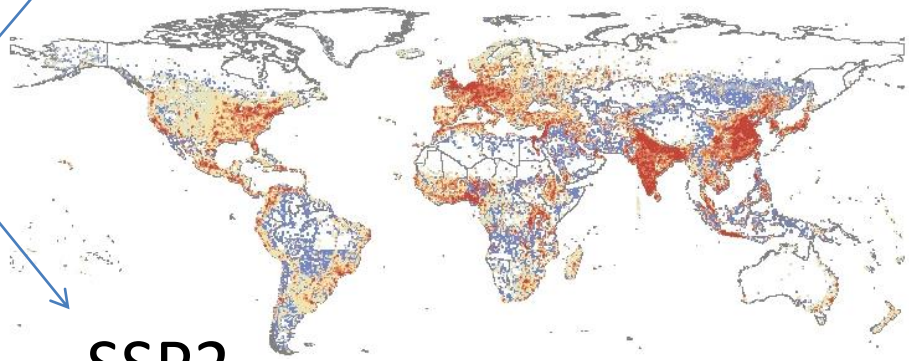
GDP in the future

2000 → 2080

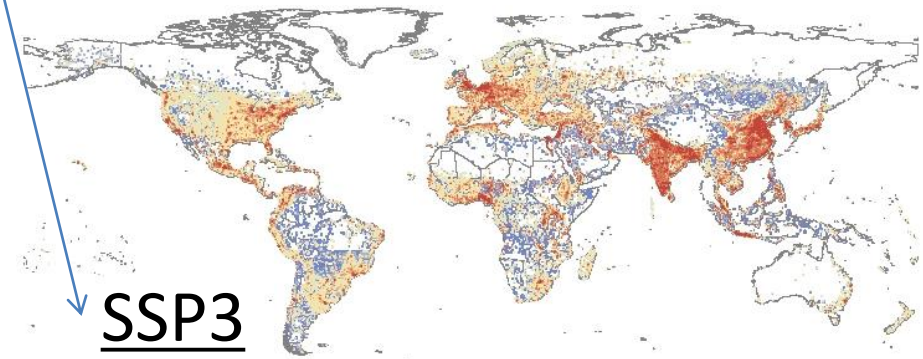




SSP1



SSP2



SSP3

Future transport network innovation scenarios are to be developed

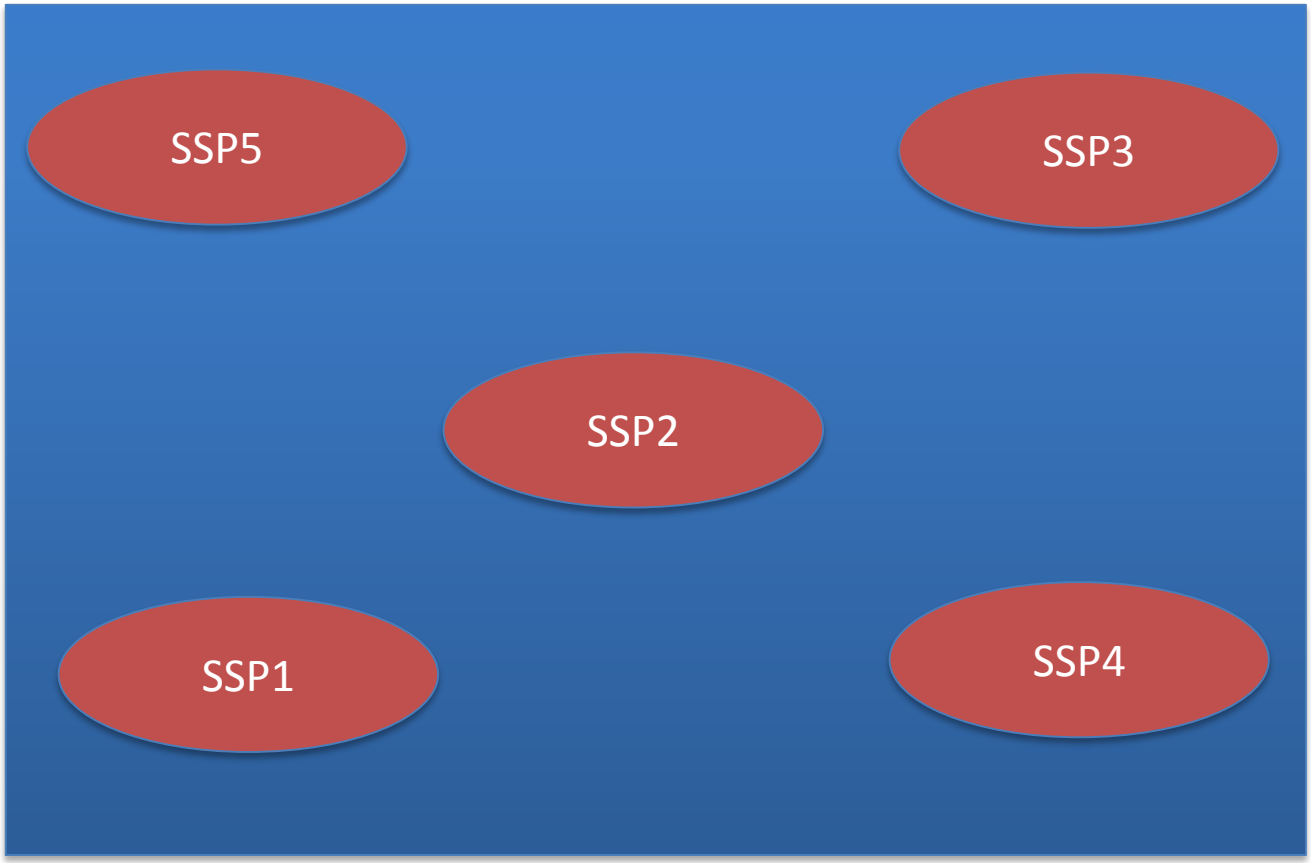
(Murakami and Yamagata 2014, in prep.)

SSP compatible Urban development scenarios

Difficult
Dispersion
Urban form

Climate Change Mitigation

Easy
Multipolar
compact
Urban form



Easy
Property is
diversified
spatially

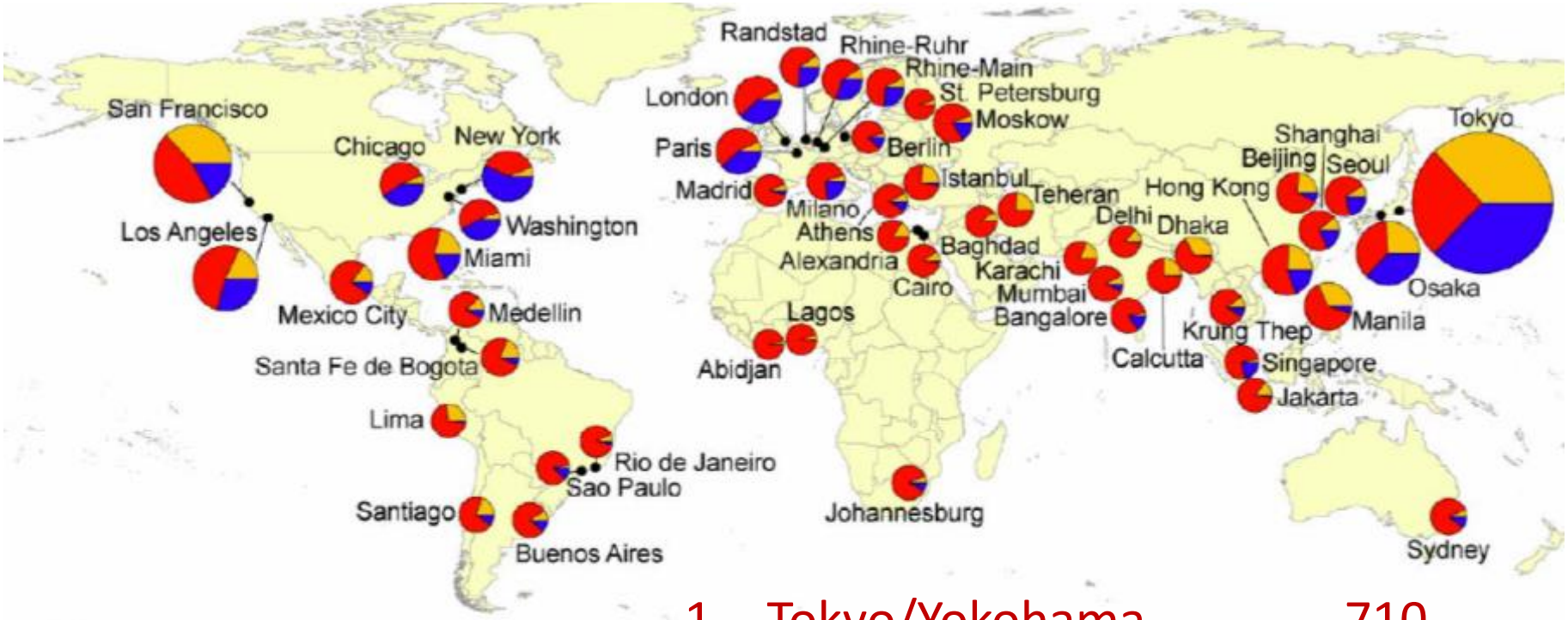
Climate Change Adaptation

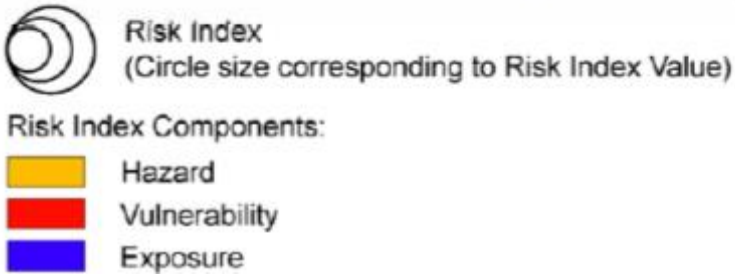
Difficult
Property is
concentrated to
high hazard area

(Yamagata, 2015)

Natural hazard risk index

The Munich Re 2002
(Reinsurance company)



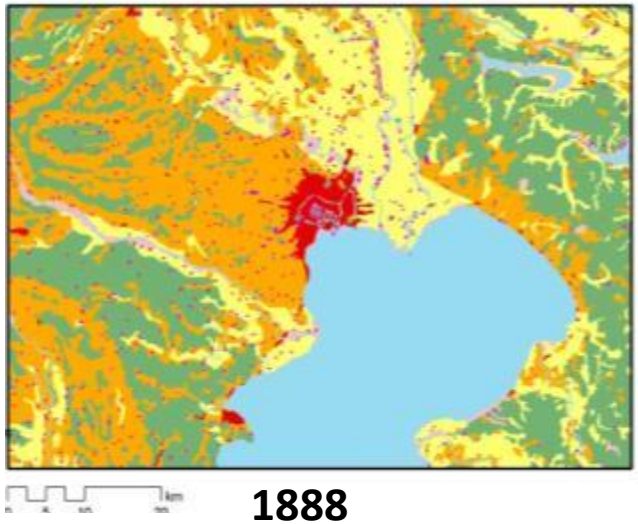


1. Tokyo/Yokohama 710
2. San Francisco 167
3. Los Angeles 100
4. Osaka/Kobe/Kyoto 92
5. ……

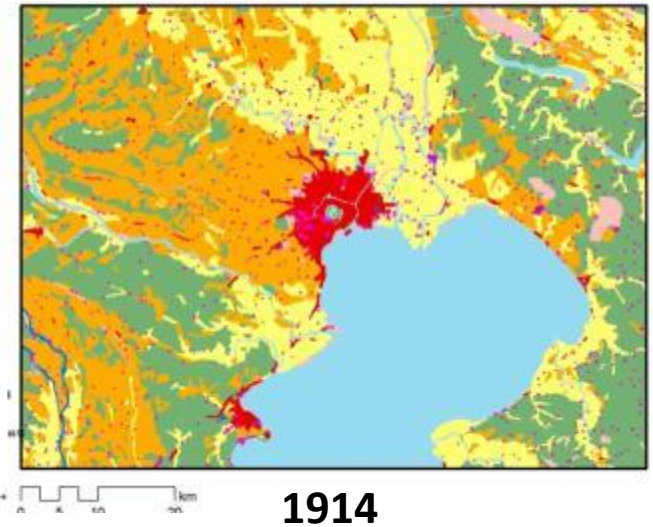
Urbanization in the Tokyo metropolitan area

1888 to 1975 (Estimated from the GSI Regional Planning Atlas)

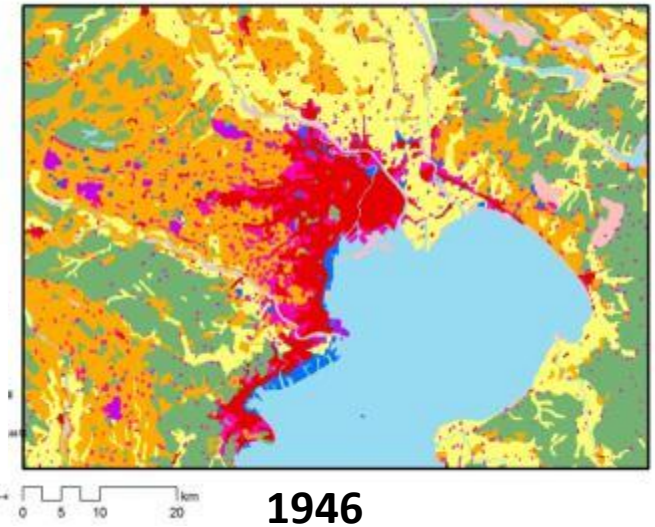
- Built-up area
- Industry area
- settlement
- Airport
- paddy
- crop land
- forest
- other
- water



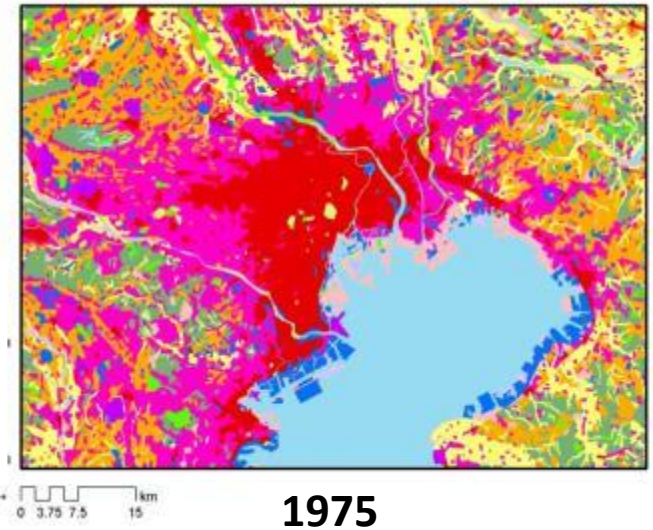
1888



1914



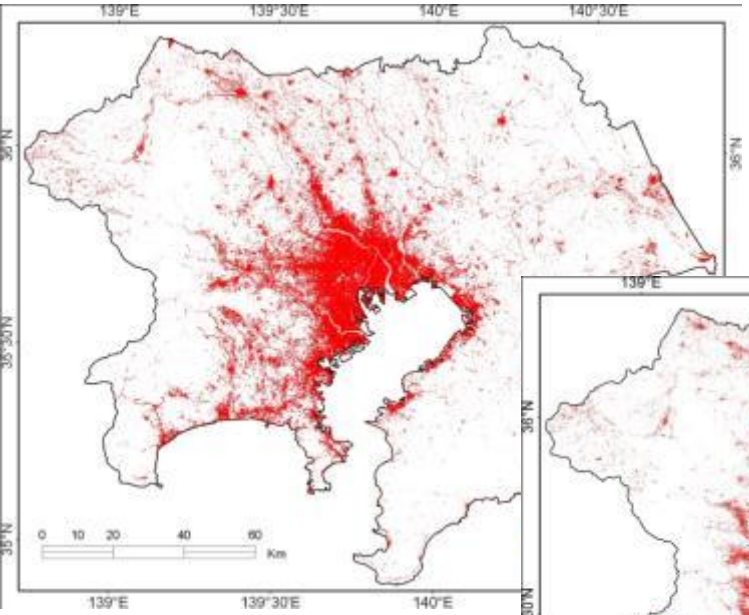
1946



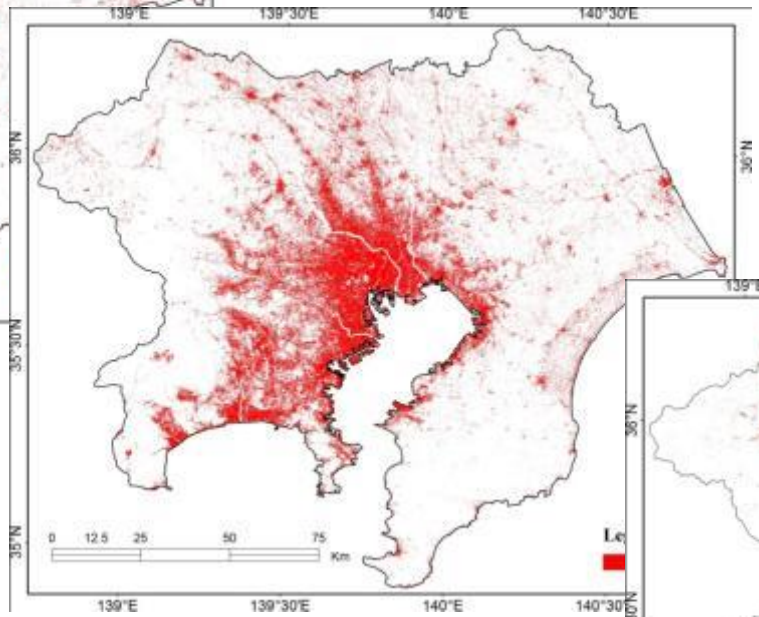
1975

>> Urban expansion and agricultural contraction of paddy & crop lands.

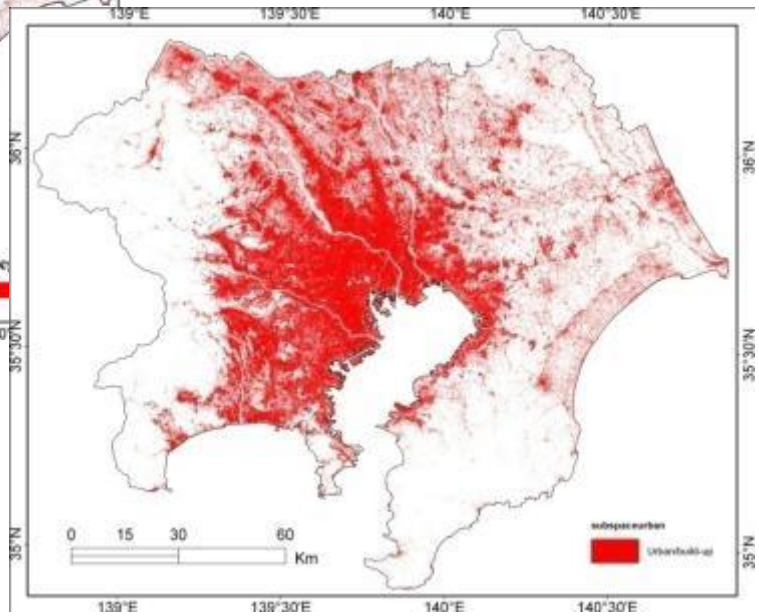
Urbanization in the Tokyo metropolitan area



1972 Landsat MSS



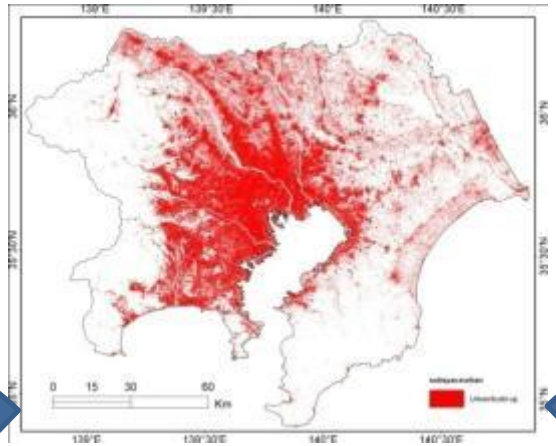
1987 Landsat TM



2002 Landsat ETM+

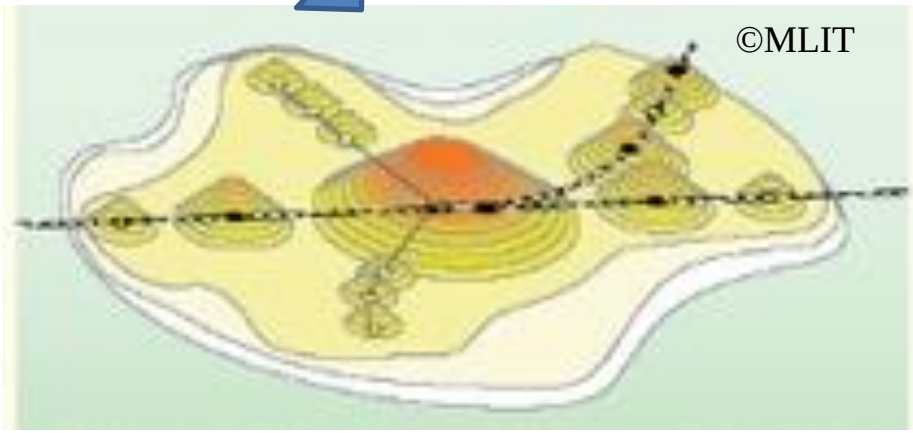
Urban land use scenarios in the future

Concentration or Dispersion?



2002 Landsat ETM+

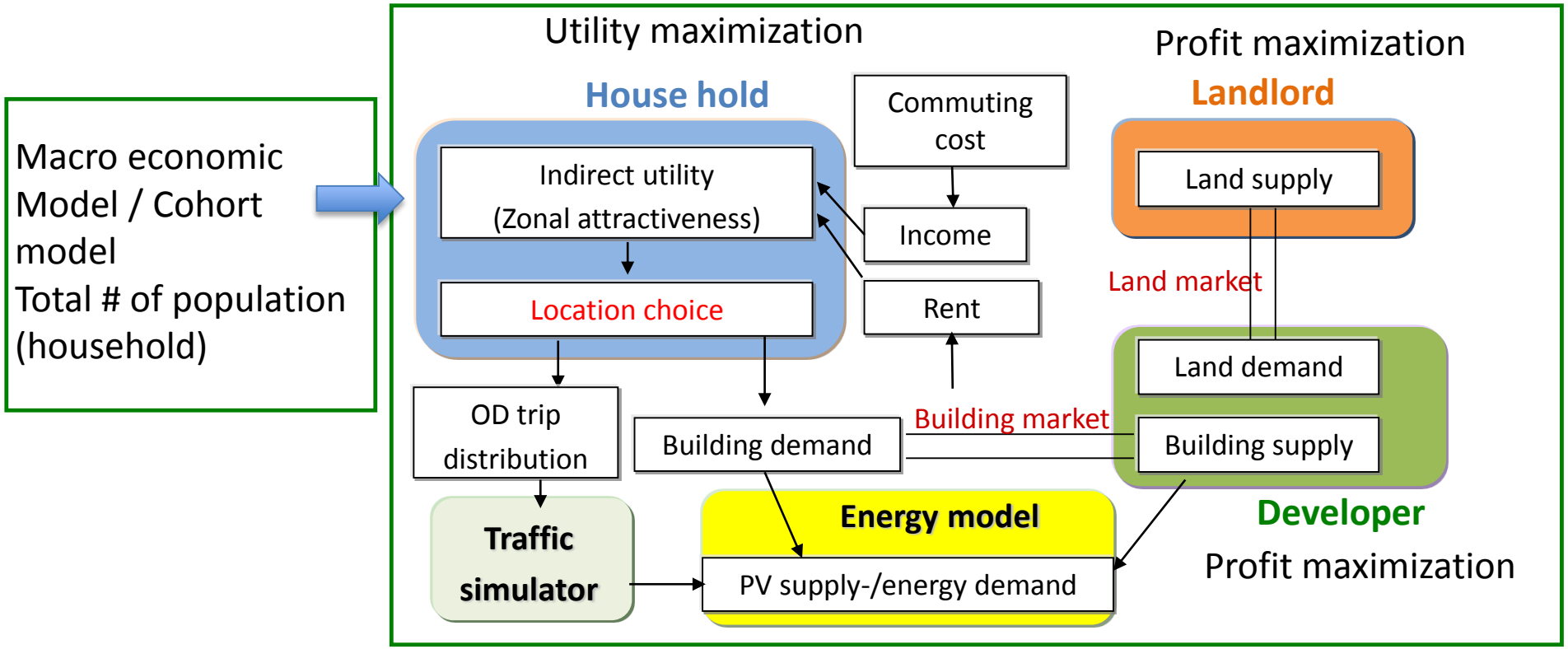
Land use scenario



Compact city

Dispersion city

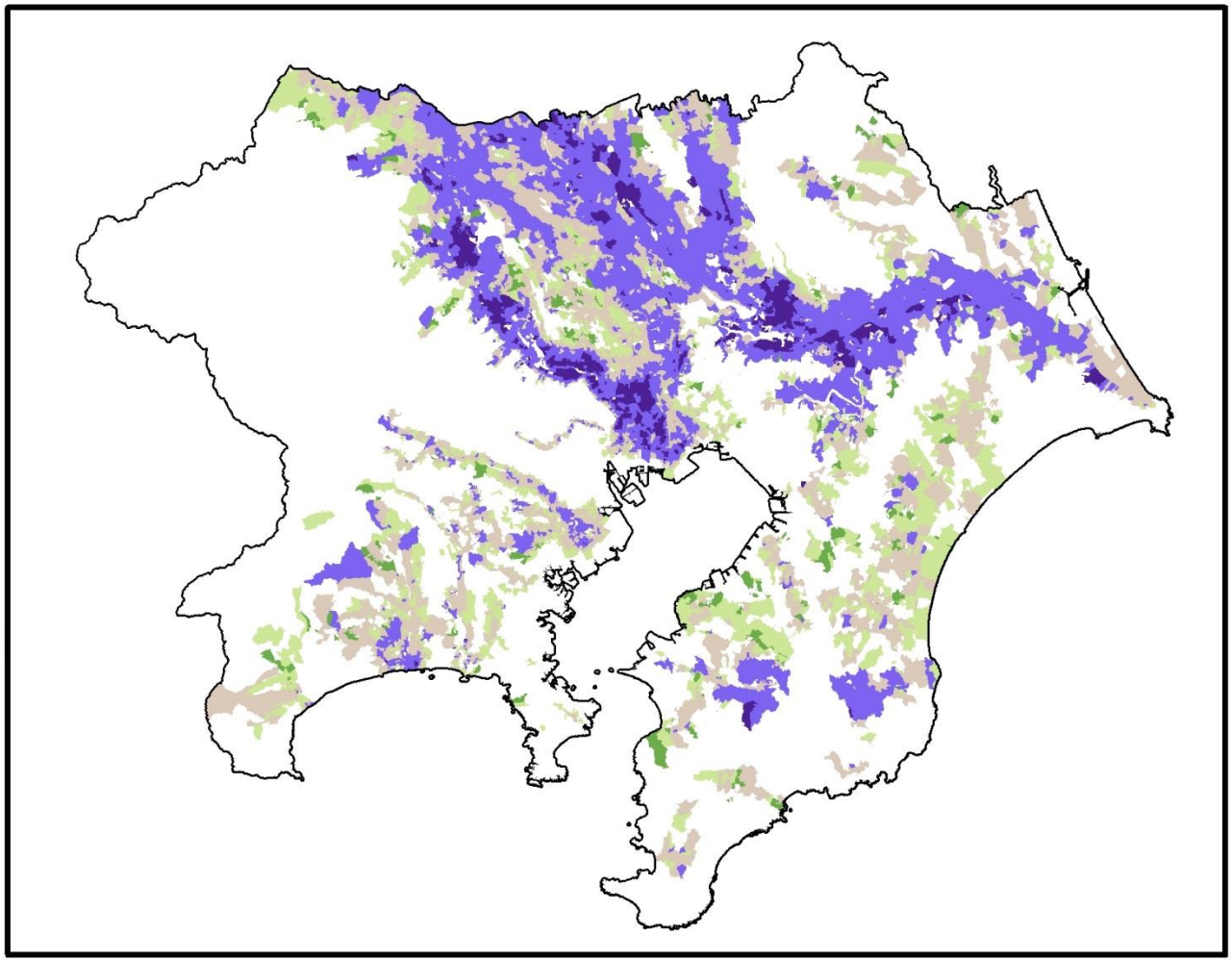
Land use-transport-energy model



We have modeled economic behaviors of household, landlord and housing developer (nonlinear optimization model)

Yamagata, Y., Seya, H., 2013. Simulating a future smart city: An integrated land use-energy model. Applied Energy 112, 1466-1474.

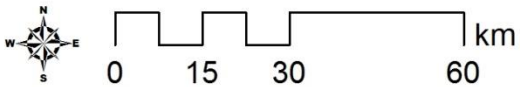
Hazard map (flooking inundation depth)



Legend

Inundation depth (Avg.)

- 5 =>
- < 5
- < 2
- < 1
- < 0.5
- 0



National land numerical information

Variables for the location choice model

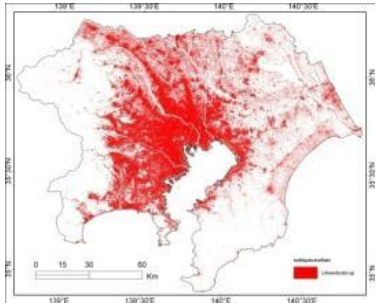
Variable	Unit	Description	Source
Ave. elevation	m	Average elevation	National land numerical information
Ave. slope	angle	Average slope	National land numerical information
Liquefaction risk	---	Risk index of liquefaction (from 0: no risk to 3: high risk)	Wakamatsu et al. (2006), Fig.***
Earthquake risk	---	Occurrence probability of earthquakes with ground motions equal to or larger than JMA seismic intensity 6–	Japan seismic hazard information station
Building-to-land ratio	%	Building-to-land ratio	UDS Co., Ltd.
Floor area ratio	%	Floor area ratio	UDS Co., Ltd.
Residential	Ratio	Proportion of residential zone	UDS Co., Ltd.
U_C	Ratio	Proportion of urbanization control zone	UDS Co., Ltd.
Commercial	Ratio	Proportion of commercial zone	UDS Co., Ltd.
ln (area)	km2	Natural logarithm of the zone area	Nippon Statistics Center Co., Ltd
Office density	---	# of office in 2006 / area	Establishment and enterprise census
W.Office density	---	Spatial weighted average of # of office in 2006 / area	Establishment and enterprise census
Office_W.Office density	---	(# of office + Spatial weighted average of # of office in 2006) / area	Establishment and enterprise census
Dist. sta.	m	Distance to the nearest train station	National land numerical information
# commuters	---	# of annual commuters of the nearest train station	National land numerical information

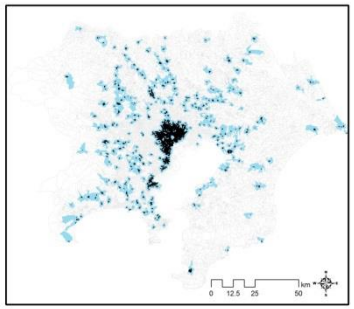
※ JMC: The Japan Meteorological Agency

Yamagata, Seya, and Nakamichi (2013) Creation of future urban environmental scenarios using a geographically explicit land-use model: a case study of Tokyo, *Annals of GIS*.

Future Urban Land Use Scenarios

Current urban area

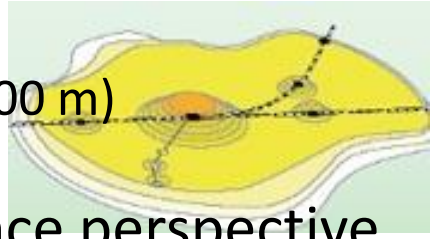




Black: city centers
Sky blue: subsidized zones

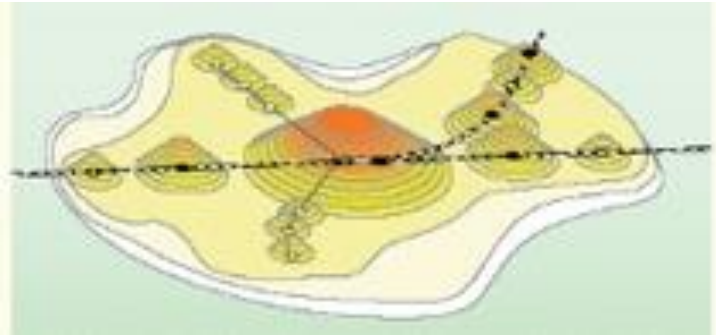
Compact scenario

- Subsidized by 1200$ /y if moving to near urban centers
  (Zones less than 500 m)



Total number of each
7 types of households
are statistically projected

Dispersion scenario (BAU)



+ resilience perspective

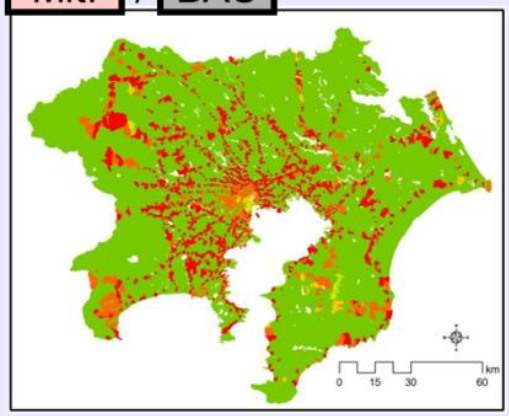
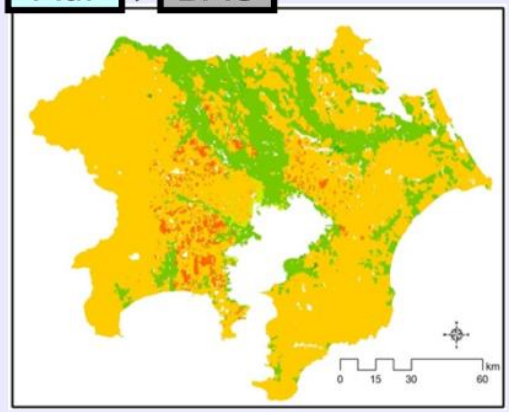
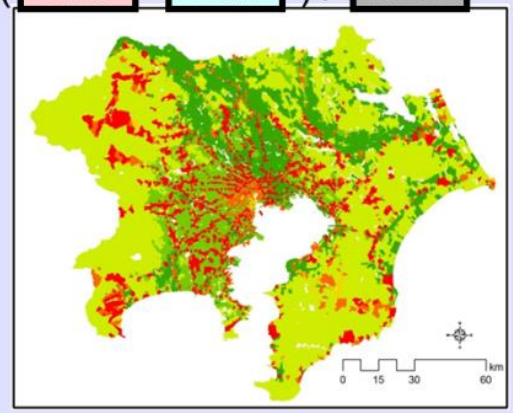
Adaptation scenario

- Subsidized if moving to near urban centers, whose flood risk is not too high

(< 5m)

Mitigation and Adaptation Scenarios

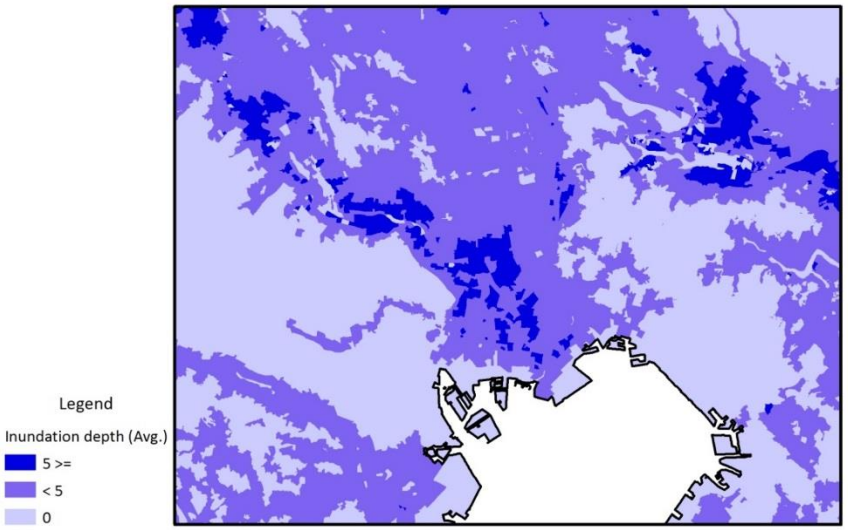
Change of population density

	w/o Mitigation	W Mitigation
w/o Adaptation	BAU	Mit. / BAU 
W adaptation	Ad. / BAU 	(Mit. + Ad.) / BAU 

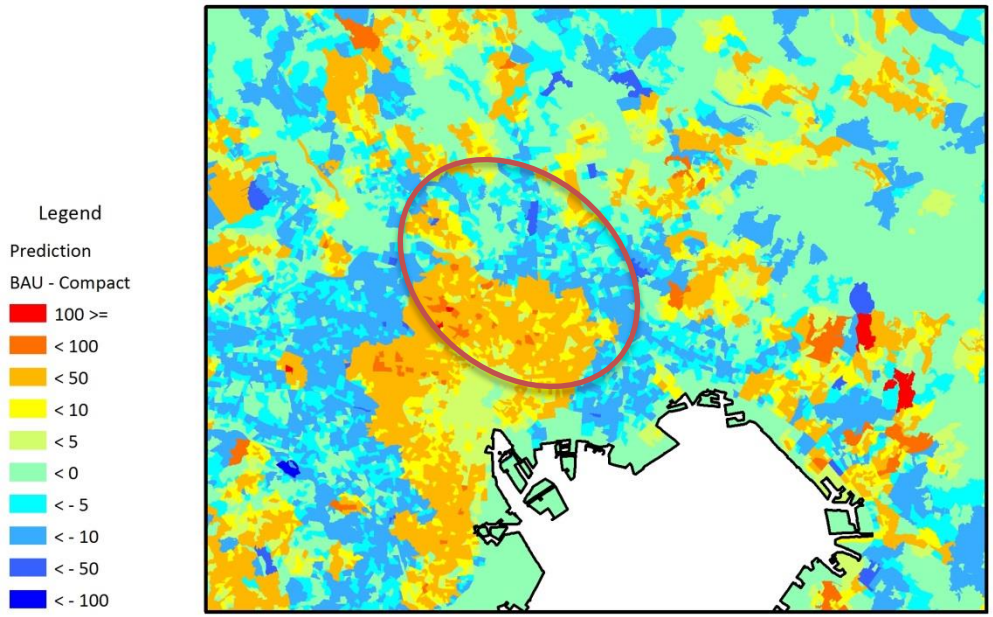
Mitigation: compact city scenario along the railways. People use more public transport to achieve low carbon society.

Adaptation: move houses from low-land areas that are potentially vulnerable to floods and coastal disaster.

Compact city scenario which also consider adaptation against flooding risks

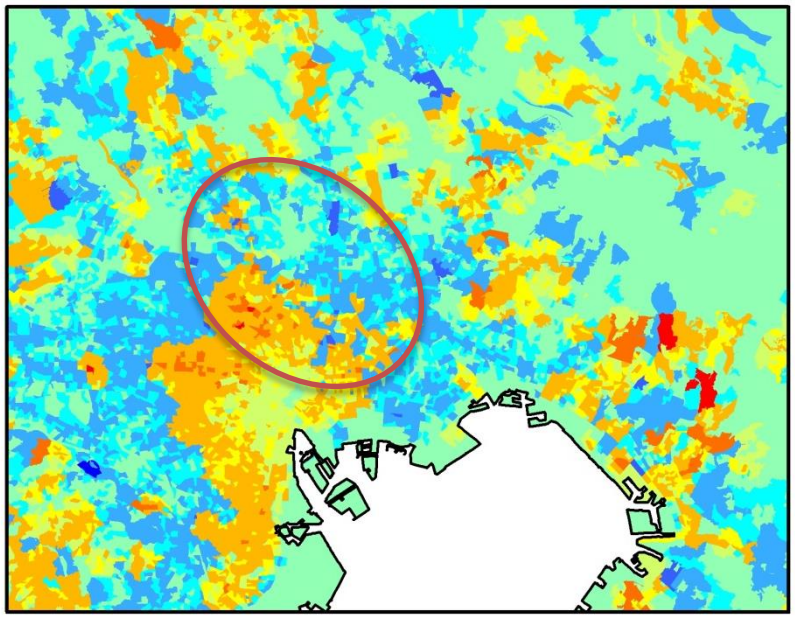


Compact - Dispersion

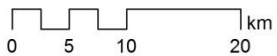


Risk reduction: –7.2B$

+Adaptation - Dispersion

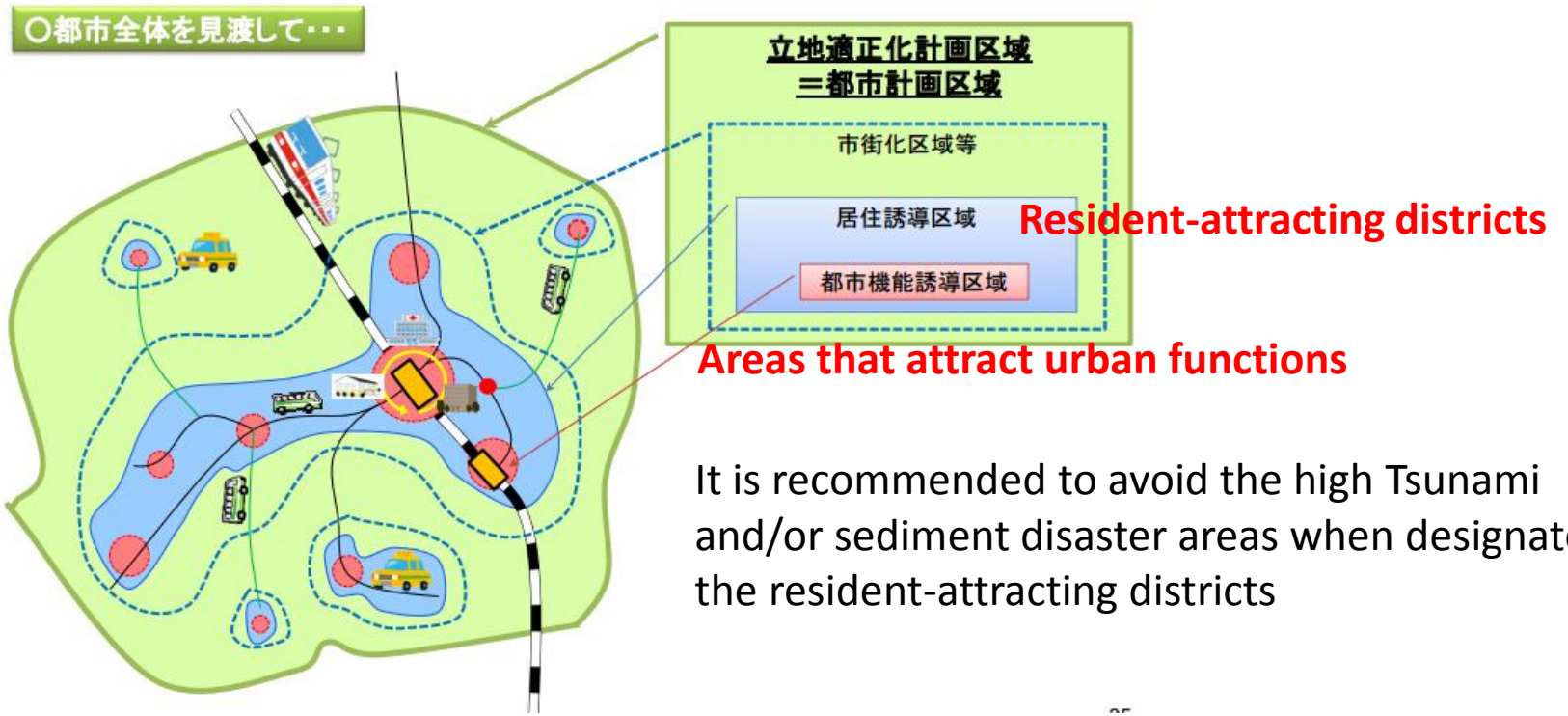


Risk reduction: –30.4B$



Revised Act on Special Measures Concerning Urban Renaissance (August 1, 2014)

- Compact cities with multipolar networks



It is recommended to avoid the high Tsunami and/or sediment disaster areas when designate the resident-attracting districts

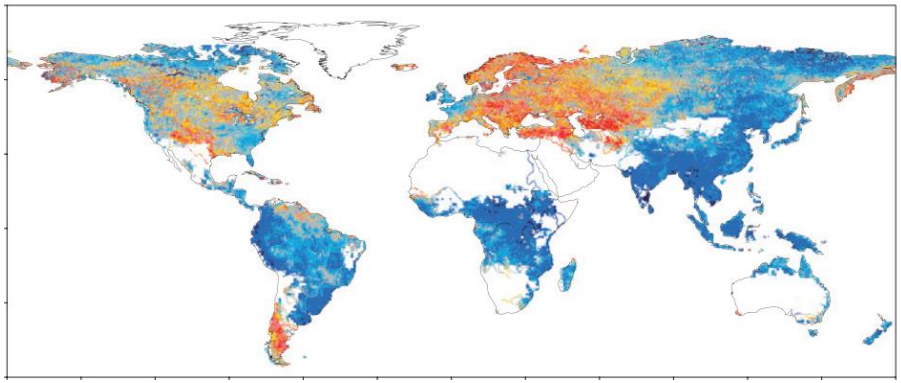
http://www.mlit.go.jp/common/001053382.pdf

Some key questions for new Project

- We need to understanding dynamics of Urbanization to project the future of cities
- Mega-cities can shrink sustainably?
  - Downsizing to multi-polar structure might be an effective strategy to manage the risks
- New life styles for the Well-being
- Future intra/inter city transport systems
- Mitigation and adaptation integration as “Urban Resilience”

Increase of flood risks

- Flood risk in 21C. (Hirabayashi et al., 2013)

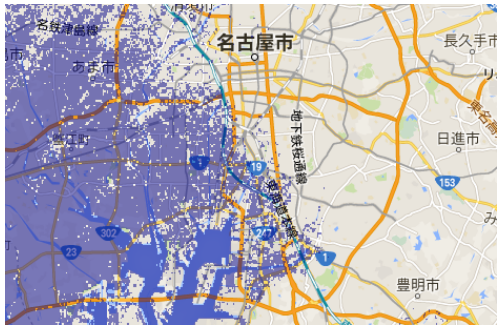


Blue : Flood increases

Red : Flood decreases

- Sea-level rise
  - Some recent studies predict that the sea-level rise can be 1m by 2100 (e.g, Robert et al., 2011).
  - The cost of sea-level rise is substantially underestimated (Michael, 2007)

Tokyo



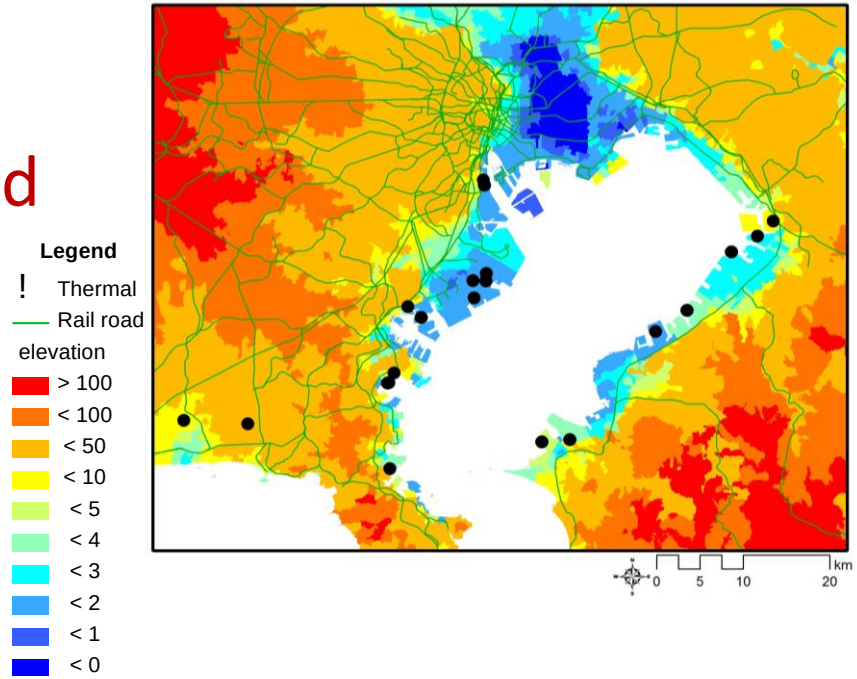
Nagoya

Osaka

Metropolitan areas after 1m sea-level rise (source: http://flood.firetree.net/)

Flood risk and urban design

- In Japan, it seems that the flood risk is not reflected to urban design sufficiently.
  - **Right figure**: Elevation and location of thermal plans.



- Underestimation of the flood risk
  - **Normality bias**
    - ✓ People tends to underestimate the possibility of suffering from disasters.
    - ✓ People tends to be too optimistic even under disaster.

→Even if flood risks are perceived, person still prefers living nearby the ocean partly due to the underestimation.

Urban management for flood risk

– Hazard risk management is needed to take proper action under flood disaster.

- Risk management in Yokohama
  – A web-GIS system of showing hazard maps is opening on public.

– If this system works well, the flood prone area must be perceived as a dangerous area, and it would decrease property values.

Source: http://wwwm.city.yokohama.lg.jp/select_map.asp

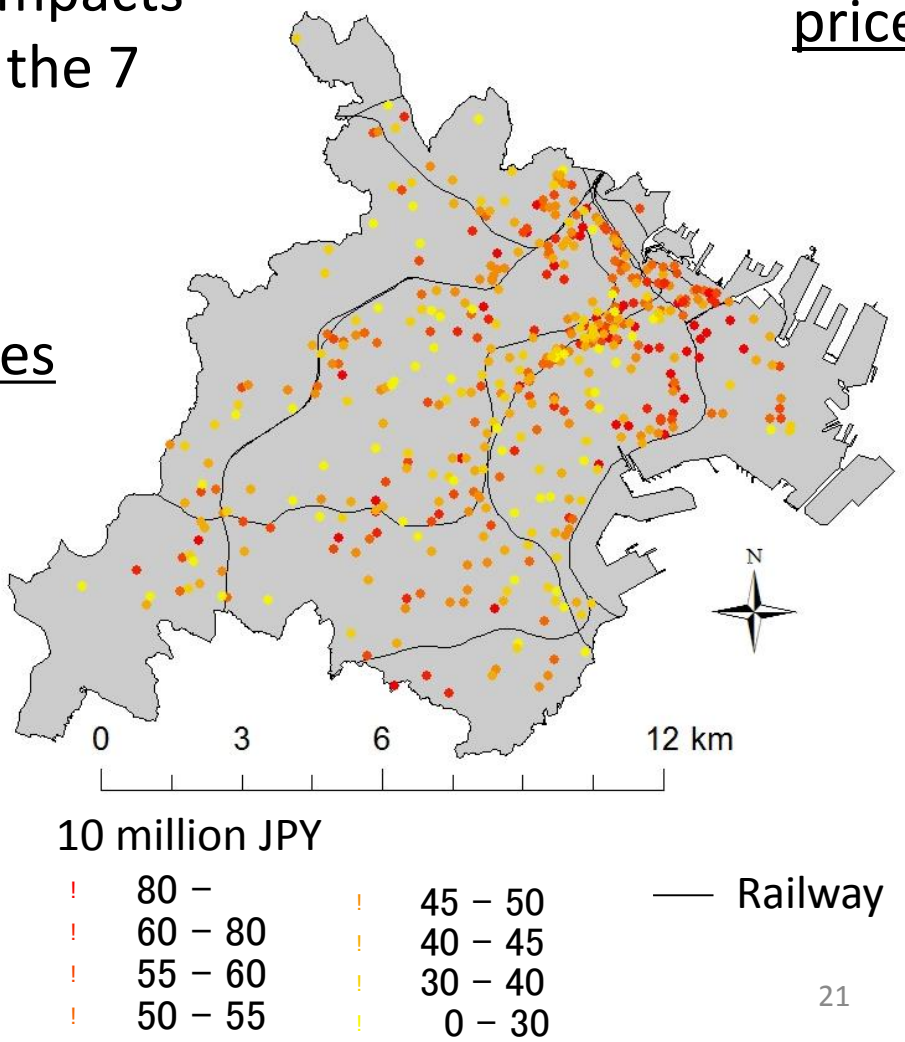
Hedonic analysis

- The impact value of the flood risk is evaluated by quantifying their impacts on **condominium unit prices** in the 7 wards in Yokohama city.

Summary statistics of the unit prices

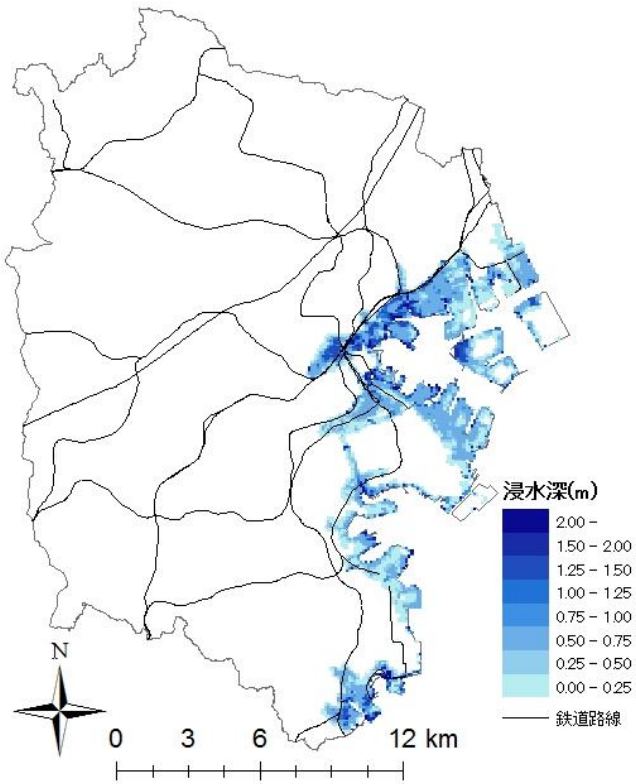
Statistics	Value (million JPY)
Average	40.87
Median	39.20
Maximum	320.0
Minimum	10.90
Standard deviation	11.82
Sample size (building / room)	694 / 27,446

Average condominium prices



Explanatory variables relating the ocean

- O-dist
  - Distance to the ocean.
- O-view
  - 3D view to the ocean .
  - It is calculated using ArcGIS 3D analyst.
- Depth
  - Estimated inundation depths under the Nankai Trough Earthquake.



The inundation depth

✓ 23 other explanatory variables (not shown here) are also introduced to control these influences.

Estimation result

- O-dist
  - Proximity to the ocean has a positive economic value (although the impact is not statistically significant).
- O-view
  - Only scenic ocean view has significant positive economic value.
- F-risk
  - Flood risk has positive economic value.

→While O-dist and O-view have positive value as expected, the negative value flood risk is not reflected adequately at all.

Estimated marginal benefit from the ocean

Red: Greater positive benefit from the ocean (O-dist + O-view + F-risk)

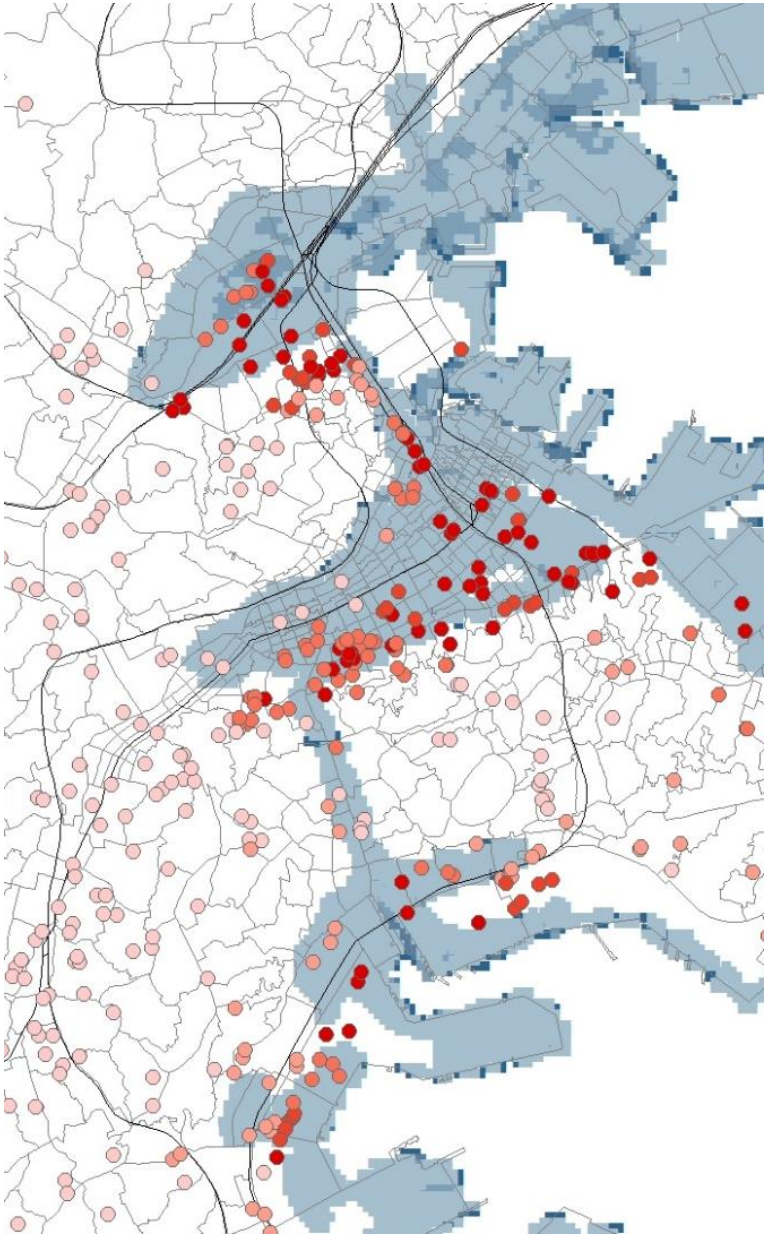
– Flood prone area attracts persons

There are several options to mitigates the flood risk

- A landuse regulation
- Embankment construct

- Policy must be chosen considering their possible influences on, e.g., human amenity, hazard risk, and natural environment.

→Scenario analyses are needed



Flood prone area

Research plan

- We plan to proceed scenario analyses to design sustainable urban development.

Developer/Policy maker

Design proposal
Visualization

Co-design

Take action toward the implementation

Development of an urban design support tool

Researcher

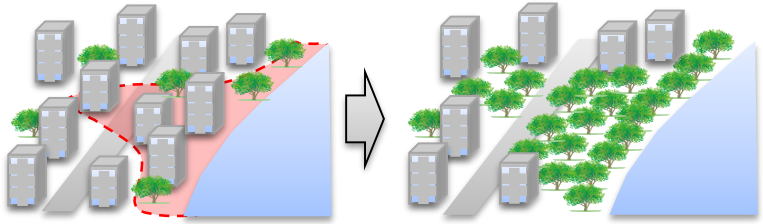
Micro-scale (**3D urban space**; 0.5m grids)

Building scenario (Material; Structure…)
Greening scenario (Allocation, volume…)

Coarser-scale (1km grids)

The landuse-transportation-energy model -based scenario analysis (e.g, regulation…)

Example: A scenario of installing a green belt on flood prone areas.



Quantification

Amenity	Hazard risk	Environ. efficiency	Econ. impact	…