Chapter 12
Spatially Explicit Land-Use Modelling for Assessing Climate-Resilient Sustainable Urban Forms

Yoshiki Yamagata and Daisuke Murakami

12.1 Introduction

In December 2015, 196 countries agreed the Paris Agreement toward sustainable development to hold the increase in the global average temperature well-blow 2°, to increase the adaptability to the climate change and foster climate resilience, and to make the financial flow consistent with a pathway towards low greenhouse gas emissions and climate-resilient development (UNFCCC 2015; url: http://unfccc.int/resource/docs/2015/cop21/eng/l09r01.pdf).

Achievement of these goals is not necessarily straightforward. While economic development and energy intensity are the major determinants of future emissions (Marangoni et al. 2017), further economic development is projected in many developing countries (e.g., O'Neill et al. 2014; Murakami and Yamagata 2016). If high emissions are allowed, the global temperature raises up to 3.2–5.4 °C by 2100 relative to 1850–1900 (RCP 8.5). By contrast, the temperature increase is 0.9–2.3 °C in a low emission scenario (RCP 2.6) (Fuss et al. 2014). The difference is a matter. Actually, people in deadly heat area, which is 30% of the global population currently, is projected to increase up to 74% in 2100 in the high emission scenario whereas 48% in the low emission scenario (Mora et al. 2017). The temperature change increases the global flood risk approximately 187% over the risk in 2050 without climate change (Arnell and Gosling 2016). Achievement of the goals is a crucial task.

Y. Yamagata (✉)
Center for Global Environmental Research, National Institute for Environmental Studies, 16-2, Onogawa, Tsukuba, Ibaraki 305-8506, Japan
e-mail: yamagata@nies.go.jp

D. Murakami
Department of Statistical Modeling, Institute of Statistical Mathematics, 10-3, Midor-Cho, Tachikawa, Tokyo 190-8562, Japan
e-mail: dmuraka@ism.ac.jp

Y. Yamagata and A. Sharifi (eds.), *Resilience-Oriented Urban Planning*, Lecture Notes in Energy 65, https://doi.org/10.1007/978-3-319-75798-8_12

It is critically important to make cities low carbon and adaptive to climate change. Actually, world total cities account for more than 70% of the total emissions (Gurney et al. 2015), and the percentage is projected to increase rapidly. Because the use emissions of new infrastructure constitutes the major part of future emissions (Creutzig et al. 2016), carbons are potentially reduced considerably by implementing low carbon urban systems.

It is important to note that climate change impacts changes regions by regions as shown in the Fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC AR5; see Stocker 2014). For example, flood risk is increasing especially in South and South-East Asian countries whereas heatwave risk is increasing especially in African countries. Adaptation policy must be considered while understanding possible climate risks in each city.

Cities have not only climate issues but also many other issues relating sustainability. For example, “urban shrinkage” is required in cities facing population decrease, which is becoming a typical path in developed countries (Turok and Mykhnenok 2007; Großmann et al. 2013). Effective policy making is needed to reshape cities while saving infrastructure management cost, increasing greens, and reducing carbons. Just like adaptation policy that must be considered city by city, there is no ‘one-size-fits-all’ approach to urban shrinkage (Haase et al. 2016) because desirable city shape changes depending on population composition, industrial structure, existing transportation network, and so on.

This study focuses on especially how to achieve urban shrinkage in the developed countries, where massive population decrease is expected in the near future, considering trade-off/synergy among factors, including low carbon, climate resiliency, eco-urbanism and so on. To achieve such a “wise shrink”, we show how a urban form assessment tools can be used to compare possible land use scenarios (e.g., business as usual scenario and wise shrink scenario) quantitatively. A land-use modeling approach is introduced for that purpose.

12.2 Land-Use and Sustainability

Quantitative approaches for evaluating urban policies include top-down approaches (e.g., material flow analysis; see Ayres and Kneese 1969), bottom-up approaches [e.g., agent-based approach (Benenson 2004); land-use modeling approaches (e.g., Yamagata et al. 2013)], and their hybrid (e.g., Chrysoulakis et al. 2013) (see, Chen et al. 2014). Among them, we focus on the last one. Section 12.2.1 introduces a background about why we focus on the land-use modeling, Sect. 12.2.2 reviews the modeling approaches, and Sect. 12.3.3 reviews quantitative analysis results on land-use and sustainability.

12.2.1 Local Climate Zones (LCZs) and Land-Use Modeling

Land-use is known as a key factor determining sustainability; it influences urban temperature, emissions, disaster risks, and natural environment. Under such a background, Local Climate Zoning (LCZ) classification scheme is launched by Stewart and Oke (2012). LCZs consist of 17 zones that are based on their impact for urban climate (see, Stewart et al. 2014); the zones are clarified based on height and density of building and trees, perviousness, and thermal admittance. The LCZ scheme is applying in an increasing number of cities towards a globally consist land classification [see, the World Urban Databased and Access Portal Tools (WUDAPT; http://www.wudapt.org/)].

If a tool to evaluate goodness of sustainability policies using the LCZs is developed, sustainability policy in each city can be evaluated in a unified scheme. The tool would be beneficial to make cities across the world sustainable efficiency.

Thus, we focus on land-use modeling that potentially contribute to establish such a tool.

12.2.2 Review on Land-Use Models

Based on Van Schrojenstein et al. (2011), land-use models are classified as follows:

(a) Extrapolation of past trend of land-use changes to the future
(b) Estimation of land use based on the characteristics of each zone, such as accessibility and soil. For example, zones with good access to railway station would need a greater chance to become urban land than zones with poor accessibility. Regression model is typically used for the estimation (see, Hoek et al. 2008).
(c) Estimation of land use based on neighboring relationship. For example, a zone surrounded by wasted lands tends to be a wasted land zone as well. The cellular automata (Walfman 1983), Markov-Chain methods (e.g., Muller and Middleton 1994) are classified into this approach. Statistical land-use models considering both (b) and (c) in the former classification have been extensively studied in the last decade (e.g., Chakir and Parent 2009; Brady and Irwin 2011; Li et al. 2013; Yoshida and Tsutsumi in press).
(d) Estimation of location of residences, offices, industrial firms, and so on, and the resulting land-use, through a modeling of agents' behavior. The spatially-explicit urban land-use model (SULM; e.g., Ueda et al. 2013; Yamagata and Seya 2013), which we focus, is categorized herein.

Recently, land-use models describing agents' (actor's) behavior (d) is becoming popular as computer performance advances and more of micro-scale spatial data (e.g., road network data, district level statistics), which are useful to model urban activities, are available. Among agent-based models, the SULM is advantageous in that its agent's behaviors are described based on an economic equilibrium theory (e.g., Brady and Irwin 2011; Koomen et al. 2015). For example, the SULM for Japan (e.g., Ueda et al. 2013; Yamagata and Seya 2013) describes the utility maximization behavior of households and profit maximization behavior of developers and landlords. Since the late 1980s, the effectiveness of this model has been demonstrated through benefit evaluations of transportation policy (e.g., Sato and Hino 2005; Chen et al. 2013), land-use policy (e.g., Nakamichi et al. 2013; Yamagata and Seya 2013; Yamagata et al. 2013), and so on.

12.2.3 Land-Use, Compact City, and Sustainability

Urban compaction has been alluded as an idealized urban form that reduces carbons, saves maintaining cost, increases greens, and revitalize central areas, which are typically declining in the car dependent society. In recent years, in which city populations in developed countries are declining, wise urban shrinkage is even more important. Thus, quantitative analyses is now needed to achieve wise shrink.

Numerous studies have shown benefits of urban compaction in terms of low carbon (e.g., Taniguchi and Ikeda 2005; Kennedy et al. 2009; Baur et al. 2013, Mishalani et al. 2014), revegetation (e.g., Beatley 2012), transportation cost reduction (Kaido and Kwon 2008; Howley 2009), and infrastructure cost saving (e.g., Burchell et al. 2002; Morikawa 2011). At the same time, a number of studies have negative comments on city compaction. Mindali et al. (2004) and Longden (2015) suggested that compaction city policy does not necessarily have statistically significant contribution on carbon reduction. Newman (2005) suggested that a compaction, which increases population density and decreases greens, lowers livability. Besides, concentration of people and stocks in one area can make a city vulnerable against natural disasters and man-made risks (see, Dodman 2009).

In sum, urban compaction/shrinkage policy must be designed in a sensible way; if not, it does not contribute to sustainability.

12.3 The Spatially-Explicit Urban Land-Use Model (SULM)

12.3.1 Overview

SULM estimates the behaviors of households, developers, and landlords, aggregated into N zones indexed by $i \in \{1, 2, \ldots N\}$. In Japan, SULM is slightly modified to reflect the situation of the real estate market that the land price market and the real estate market are separated. Figure 12.1 shows an overview of the model. In this model, households select their own residential locations, developers supply

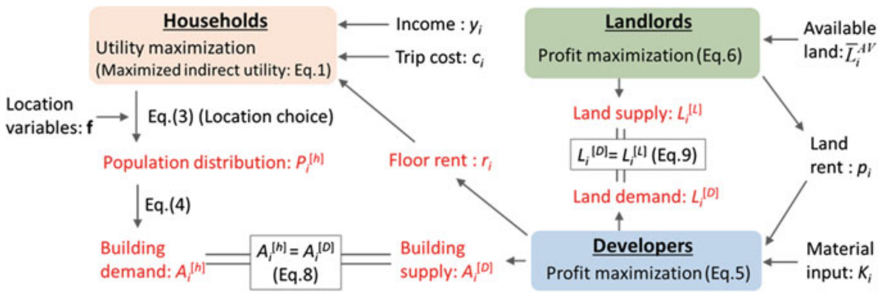

Fig. 12.1 Image of SULM. Red: endogenous variables to be calibrated; black: exogenous variables that are assumed to be fixed (*Source* Yamagata et al. 2016)

buildings to the households with a certain floor rent, and absentee landlords supply land to build the buildings to the developers. In other words, households and developers transact in a building market whereas the developers and landlords transact in a land market. During the transactions, households maximizes their own indirect utility, and the developers and the landlords maximize their own profits. The SULM describes a partial equilibrium state under these utility/profit maximization behaviors, and estimate the resulting population, total floor area, building area, and floor rent in each zone.

Models for households, developers, and landlords are described below:

12.3.2 Model for Households

The households' indirect utility function in i-th zone, V_i, is formulated as

$$V_i = \ln y_i - \alpha_a \ln r_i - \alpha_x \ln c_i. \tag{12.1}$$

y_i is the average income per capita, r_i is the residential floor rent per area, c_i is the generalized cost of a private trip. Equation (12.1) assumes that the utility of households increases if income, y_i, is large relative to floor rent, r_i, and travel costs, c_i. In Eq. (12.1), y_i and c_i are assumed given, and the floor rent, r_i, is estimated by maximizing V_i. The coefficients α_a and α_x may be given specified based on Roy's identity equation as follows (see Yamagata and Seya 2013):

$$a_i = \alpha_i \frac{y_i}{r_i},\ x_i = \alpha_x \frac{y_i}{c_i},\ z_i = \alpha_z y_i, \tag{12.2}$$

$$s.t.\ \alpha_a + \alpha_x + \alpha_z = 1\ \alpha_* > 0$$

where a_i is the presidential floor area per person, and z_i is the composite good per person. The coefficients α_a, α_x, and.α_z are estimated by applying the ordinary least squares (OLS) to each of the equations in Eq. (12.2).

The residential location choice behavior of household type h (e.g., one-person, married couple, and so on; see Table 12.1) is modeled using V_i. Specifically, the ratio for the type h households to select the zone i as their own residential location, $P_i^{[h]}$ is described by the following (aggregated) multinomial logistic regression model:

$$P_i^{[h]} = \frac{\exp(v_i^{[h]})}{\sum_j v_j^{[h]}}, \; v_i^{[h]} = \delta^{[h]} V_i + \mathbf{f}'_i \chi^{[h]}, \tag{12.3}$$

where $\delta^{[h]}$ is the coefficient on V_i, which is given by Eq. (12.1). $\mathbf{f}_i$ is a vector variables explaining the residential location choice and $\chi^{[h]}$ is a vector of their coefficients. The suffix "$[h]$" means that the coefficients $\delta^{[h]}$ and $\chi^{[h]}$ change depending on the household types h. These coefficients can be estimated by applying the aggregated multinomial logistic regression approach. Equation (12.3) simply assumes that the indirect utility and other explanatory variables determine the residential location choice.

Once $P_i^{[h]}$ is estimated, the floor area demand in the i-th zone is estimated as follows:

$$A_i = a_i \sum_{h \in H} \bar{N}^{[h]} s_i^{[h]} P_i^{[h]}. \tag{12.4}$$

$\bar{N}^{[h]}$ is the total number of type h households across the study area. $s_i^{[h]}$ is the number of persons for each household of type h in zone i.

12.3.3 Model for Developers

Developers are assumed to obey the following profit maximization behavior:

$$\underset{i}{\overset{[D]}{\Pi}} = \max_{A_i^{[D]}, L_i^{[D]}} \left(r_i A_i^{[D]} - p_i L_i^{[D]} - mK_i \right), \tag{12.5}$$

Table 12.1 6 sub-scenarios (Compact/Wise shrink scenarios × revegetation scenarios)

Revegetation scenario Conversion of building lands reduced by policies	Compact scenario	Wise shrink scenario
- To any land-use type (leave it to chance)	Compact_0	Wise shrink_0
- To any type of green land (i.e., paddy fields, agricultural areas, forest, wildland, or park/recreation areas)	Compact_g1	Wise shrink_g1
- The same with g1 except that only park/recreation areas are allowed for districts with population increase.	Comact_g2	Wise_shrink_g2

$$A_i^{[D]} = v\left(L_i^{[D]}\right)^{\mu_1}\left(K_i\right)^{\mu_2}$$

$A_i^{[D]}$ is the floor area supplied from the developers to the households, $L_i^{[D]}$ is the land area supplied from the landlords to the developers, and p_i denotes the land rent. K_i is the material inputted for the production of floor service, and m is the price for the material construction. The parameters μ_1, μ_2, v can be estimated by applying OLS to equations derived by solving Eq. (12.5) (see, Yamagata and Seya 2013). Equation (12.5) assumes that the developers determine $A_i^{[D]}$ and $L_i^{[D]}$ to increase their benefit $r_iA_i^{[D]}$ while reducing the cost for land purchase $p_iL_i^{[D]}$, and, material input, mK_i.

12.3.4 Model for Landlords

Landlords are assumed to obey the following profit maximization behavior

$$\prod_i^{[L]} = \max_{L_i^{[L]}}\left(p_iL_i^{[L]} - C(L_i^{[L]})\right) \tag{12.6}$$

$$C(L_i^{[L]}) = -\sigma_i\bar{L}_i^{AV}\ln\left(1 - \frac{L_i^{[L]}}{\bar{L}_i^{AV}}\right), \tag{12.7}$$

where $L_i^{[L]}$ denotes residential land supplied from the landlords, $C(L_i^{[LH]})$ denotes the land maintaining cost, $\bar{L}_i^{AV}$ represents the available land area and σ_i denotes a parameter. Equation (12.6) assumes that the landlords determines $L_i^{[L]}$ to increase the benefit $p_iL_i^{[L]}$ and reduce the cost, $C(L_i^{[L]})$.

12.3.5 Equilibrium Condition

As illustrated in Fig. 12.1, there are two markets in this model: the building markets between households and developers; and. the land transaction between developers and landlords. Under a partial equilibrium, supply and demand must be balanced in these two transactions. These equilibriums are formulated by Eqs. (12.8) and (12.9), respectively:

$$A_i^{[h]} = A_i^{[D]}, \tag{12.8}$$

$$L_i^{[h]} = L_i^{[L]} \tag{12.9}$$

Roughly speaking, population, the building area, and other variables shown in red in Fig. 12.1 under a partial equilibrium are estimated by iteratively maximizing the objective function for each agent under the constraint of Eqs. (12.8) and (12.9) until the values of the estimated variables converge.

For further detail about the SULM and its calibration, see Yamagata and Seya (2013).

12.4 Application of the SULM in the Tokyo Metropolitan Area

12.4.1 Outline

This section illustrates an application of the SULM to the Tokyo metropolitan area. The analysis units are 22,603 micro districts in that area. For full descriptions, see Yamagata et al. (2016).

Based on Voss (2006), the Tokyo metropolitan area has the highest insurance risk among megacities in the world. Actually, based on the Headquarters for Earthquake Research Promotion, Japan (http://www.jishin.go.jp/main/index-e.html), the probability of suffering from an earthquake with magnitude 8.0 class within the next 30 years is estimated 70% as of January 1, 2017. Besides, extreme climate events are projected to increase gradually in Asian countries including the Tokyo area (e.g., Stocker 2014), and the flooding risk will also increase as well (Hirabayashi et al. 2013). Adaptation to climate risks is an emergent task is in the target region. On the other hand, depopulation is another problem in Japan. Although the population around Tokyo is still growing, it is projected to decrease from around 2020. Urban compaction is also an important issue in this area.

12.4.2 Scenario

Based on the above, we developed the following scenarios for 2050 emphasizing urban compaction and disaster risk adaptation:

- Business-As-Usual (BAU) scenario: Any regularization is not introduced, and the past trend on populations and number of households in each districts (source: National Census) are projected by the log-linear extrapolation method.
- Compact scenario: Compact policy is introduced. In that policy, residents living within 500 m from central areas are subsidized by 1200 USD/year, which is the same amount as the subsidy in the successive compact city policy in Toyama, Japan (e.g., 1200 USD/year is added in their income, y_i). The central areas are defined by the minor districts whose office densities are statistically significantly greater than the other districts. The statistical significance is evaluated based on the local Moran's I statistics (Anselin 1996) (see Yamagata and Seya 2013).

– Wise shrink scenario: Compact policy and adaptation policy is introduced. The former is the same with the policy in the Compact scenario. The latter haves the available residential land $\bar{L}_i^{AV}$ in districts whose average flooding depth is more than 0.5 m.

Figure 12.2 displays zones subsidized in the Compact and Wise shrink scenarios. Figure 12.3 shows the flood hazard [anticipated flooding death (source: the National Land Numerical Information download service [NLNI]: http://nlftp.mlit.go.jp/ksj-e/)], which is considered in the Wise shrink scenario, and earthquake hazards [seismic intensities exceeding 6.5 within 30 year (source: Japan Seismic Hazard Information Station: http://www.j-shis.bosai.go.jp/en/)]. Although we does not explicitly consider the earthquake hazard, because flood hazard and earthquake hazard have similar spatial patterns, the regulation imposed in the Wise shrink scenario mitigates the earthquake risk too.

For further information on the SULM implementation, see Yamagata et al. (2016).

12.4.3 Result: Population Distribution

The populations, building areas, floor areas, and floor rents in each district in 2050 under the BAU, Compact, and Wise shrink scenarios are estimated by applying the SULM.

Differences of estimated district populations under the Compact and Wise shrink scenarios relative to the BAU scenario are plotted in Fig. 12.4. As expected, the Compact scenario concentrates populations in the central area. By contrast, the Wise Shrink scenario does not concentrates like that. This is because the flood risk is high in the central area (see Fig. 12.3). The Wise shrink decreases the population by 23,996 people inside the area with a flooding depth of more than 0.5 m, while the Compact scenario increases the population by 1617 people. It is also found that the Wise shrink scenario decreases population in areas with high earthquake risk

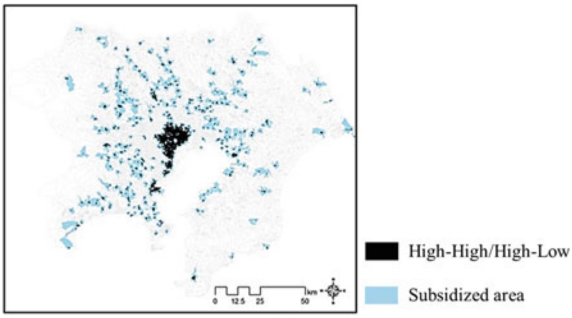

Fig. 12.2 Central areas (black) and areas subsidized areas in the compact policy (blue) (*Source* Yamagata and Seya 2013)

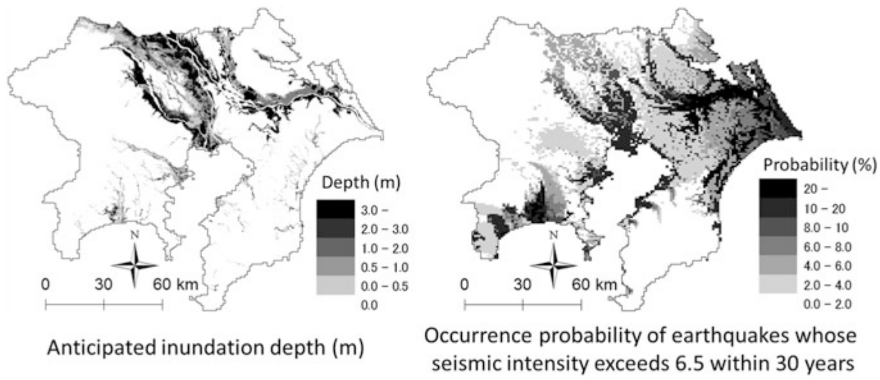

Fig. 12.3 Flood hazard (left) and earthquake hazard (right) (*Source* Yamagata et al. 2013)

whereas the opposite is true for the Compact scenario. The result clearly shows that usual compact city policy can make cities inadaptive to climate risks, and that an explicit consideration of disaster risks is important to avoid it.

12.4.4 Result: Revegetation

The SULM estimated building land areas in each district (i.e., L_i in Fig. 12.1) together with the populations (because the distributions of building lands are similar to population distributions shown in Fig. 12.4, it is not shown here). It is an interesting topic to clarify how to convert building land areas, which are reduced by the compact policy or the disaster mitigation policy, to green areas. To clarify it, the Compact and Wise shrink scenarios are subdivided into the 6 scenarios summarized in Table 12.1. Roughly speaking, these scenarios are (the Compact/Wise shrink scenarios) $\times$ (3 revegetation scenarios).

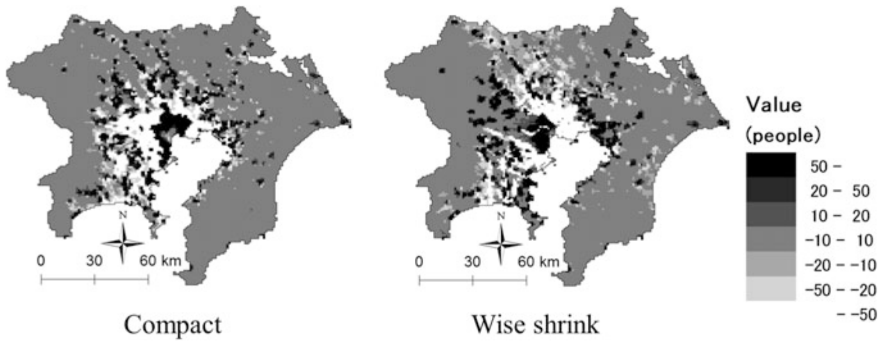

Fig. 12.4 Difference of estimated populations (2050) relative to the BAU scenario (left: the Compact scenario; right: the Wise shrink scenario). Black represents larger populations relative to the BAU scenario whereas white represents smaller populations relative to BAU

Composition of the 10 types of land uses, including 5 urban lands (Building land, Industrial land, Road, Land for public facilities, Vacant land) and 5 green lands (Paddy fields, Other agricultural land, Forest, Wild land, Park/recreation areas) under each scenario are estimated by a spatial compositional regression analysis (see, Pawlowsky-Glahn and Buccianti 2011). In this analysis, the relationship between the land-use composition in 2006 (source: NLNI) and the explanatory variables are analyzed. The variables includes populations (it is estimated from the SULM), distance to the nearest railway station, road density, elevation, distance to the nearest primary river, and dummy variables indicating urbanization control area, lake, alluvial fan, natural levee, back marsh, delta, and sandbar, respectively (source: Japan Seismic Hazard Information Station, National Research Institute for Earth Science and Disaster Prevention). Based on the relationship analysis result, the probabilities of converting the reduced building lands into each of the 10 land-use types are estimated by district. Land-use composition under each scenario are estimated by replacing the reduced building lands into other land-use following the probabilities (see Yamagata et al. 2016 for further detail).

Figures 12.5 shows estimated increases in park/recreation areas relative to the BAU scenario. The green areas under the Wise Shrink scenarios are much greater than those in the Compact scenarios. It is verified that the Wise Shrink scenarios are preferable in terms of revegetation. It is also conceivable that the degree of revegetation changes considerably depending on revegetation policy. Increase of green area is limited in the Compact_0 and Wise_0 scenarios whereas the increase is substantial under the Compact_g2 and Wise_g2 scenarios.

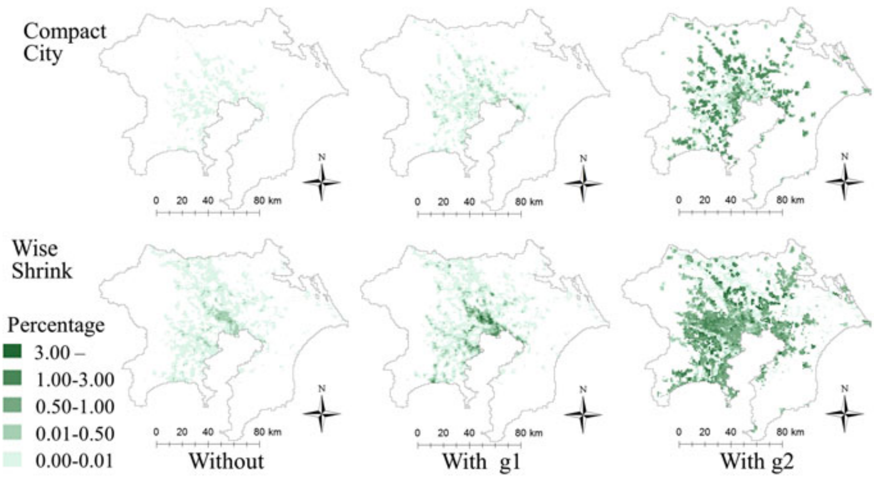

Fig. 12.5 Estimated revegetation in 2050: Park and recreation areas (*Source* Yamagata et al. 2016)

12.4.5 Result: Economic Value Assessment

This section applies the SULM analysis result to quantify the economic value of each of the 6 scenarios shown in Table 12.1. The assessment is conducted by the following steps:

(i) A hedonic analysis (Rosen 1974) is conducted to evaluate the economic values of the variables explaining accessibility, disaster risk, urban area, green area, and water area. The explanatory variables are as summarized in Table 12.2. Suppose that $x_{i,p}^{S}$ is the p-th explanatory variable, a hedonic analysis regresses $x_{i,p}^{S}$s on residential land price (we used the officially assessed land price in 2006 provided by NLNI). The resulting coefficient estimate β_p represents the economic value of the p-th explanatory variable. See Yamagata et al. (2016) for further detail.

(ii) Population and land-use distributions under each scenario are estimated using the SULM.

(iii) Economic value of each scenario is evaluated by the following equation:

$$V_{S,p} = \sum_{i} (P_i^S - P_i^{BAU}) x_{i,p}^{S} \beta_p, \tag{12.10}$$

where P_i^S is the population in i-th district estimated under the S-th scenario, and P_i^S is the population under the BAU scenario. Equation (12.10) evaluates [population change] × [economic value of each explanatory variable] by district. By

Table 12.2 Explanatory variables in the hedonic analysis

<table>
<tr><th>Category</th><th>Variables</th><th colspan="3">Description</th></tr>
<tr><td rowspan="2">Accessibility</td><td>Tokyo_dist</td><td colspan="3">Logarithm of the distance from the Tokyo Station to the nearest railway station (km)</td></tr>
<tr><td>Station_dist</td><td colspan="3">Logarithm of the distance from the nearest railway station (km)</td></tr>
<tr><td>Disaster risk</td><td>Flood_depth</td><td colspan="3">Anticipated flood depth (m)</td></tr>
<tr><td rowspan="4">Urban land</td><td>Industry</td><td rowspan="9">Area of</td><td>Industrial land</td><td rowspan="9">in 1 km grids (10 km^2)</td></tr>
<tr><td>Road</td><td>Road</td></tr>
<tr><td>Public</td><td>Land for public facilities</td></tr>
<tr><td>Vacant</td><td>Vacant land</td></tr>
<tr><td rowspan="5">Green land</td><td>Paddy</td><td>Paddy fields</td></tr>
<tr><td>Agriculture</td><td>Other agricultural land</td></tr>
<tr><td>Forest</td><td>Forest</td></tr>
<tr><td>Wild</td><td>Wild land</td></tr>
<tr><td>Park/green</td><td>Park and recreation areas</td></tr>
</table>

Source Yamagata et al. (2016)
All of these variables are collected from the National Land Numerical Information (NLNI) download service (http://nlftp.mlit.go.jp/ksj-e/index.html)

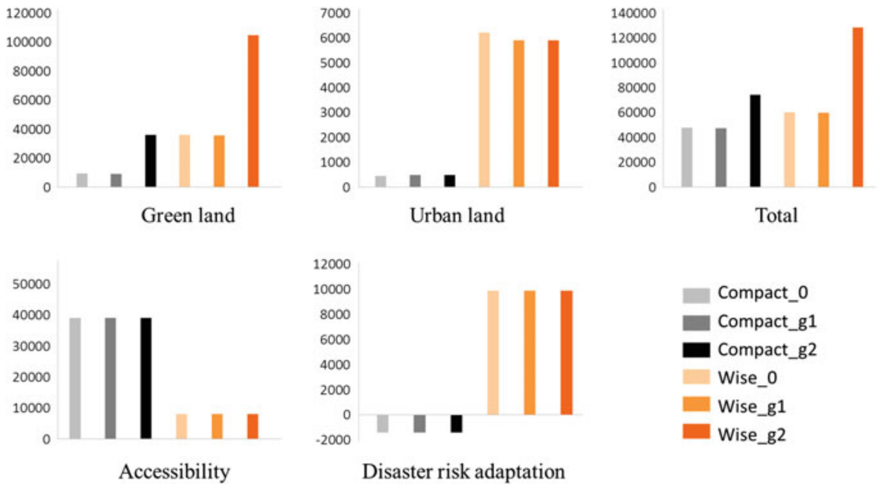

Fig. 12.6 Economic value of the scenarios (*Source* Yamagata et al. 2016)

aggregating $V_{S,p}$, which is evaluated for each $x_{i,p}^{S}$, the with respect to factors (i.e., accessibility, disaster risk, urban area, green area, and water area; see, Table 12.2) they explain, economic value of each of these factors are evaluated.

Figure 12.6 summarizes the estimated economic values of these four factors under the 6 scenarios. The values are positive if they are greater than those in the BAU scenario, and negative if they are smaller than those in the BAU scenario. The Compact scenarios greatly increase accessibility because they concentrate people around nearby railway stations. Benefits from urban land variables are also increased because more people live in urban areas, which is highly valued in the hedonic analysis (see, Yamagata et al. 2016). As a result, the total benefits from urban compaction are positive (top right in Fig. 12.6). Still, compact scenarios tend to concentrate people in high risk areas whose economic values are low (bottom middle of Fig. 12.6).

By contrast, the Wise shrink scenarios significantly increase adaptability to flood risk compared with the BAU scenarios. The benefits from all of the other factors are also higher in the Wise Shrink scenario than those in the BAU. The effectiveness of the Wise Shrink scenarios is verified. There are significant differences among the three Wise Shrink scenarios. The total benefit received in Wise_g2 is 2.15 times greater than that in Wise_0 and 2.13 times greater than that in Wise_g1. The result suggests that urban compaction must be accompanied by an effective eco-urbanism as well as disaster risk adaptation.

References

Anselin L (1996) The Moran scatterplot as an ESDA tool to assess local instability in spatial association. In: Spatial analytical perspectives on GIS, vol 111. pp 111–125
Arnell NW, Gosling SN (2016) The impacts of climate change on river flood risk at the global scale. Clim Change 134(3):387–401
Ayres RU, Kneese AV (1969) Production, consumption, and externalities. Am Econ Rev 59(3): 282–297
Baur AH, Thess M, Kleinschmit B, Creutzig F (2013) Urban climate change mitigation in Europe: looking at and beyond the role of population density. J Urban Plann Develop 140(1):04013003
Beatley T (2012) Green urbanism: Learning from European cities. Island Press
Benenson I (2004) Agent-based modeling: from individual residential choice to urban residential dynamics. In: Spatially Integrated Social Science: Examples in Best Practice, vol 42 (6-7). pp 67–95
Burchell RW, Lowenstein G, Dolphin WR, Galley CC, Downs A, Seskin S et al (2002) Costs of sprawl-2000. Transit Cooperative Research Program, USA, p 74
Brady M, Irwin E (2011) Accounting for spatial effects in economic models of land use: recent developments and challenges ahead. Environ Resource Econ 48(3):487–509
Chakir R, Parent O (2009) Determinants of land use changes: a spatial multinomial probit approach. Papers Regional Sci 88(2):327–344
Chen S, Chen B, Fath BD (2014) Urban ecosystem modeling and global change: potential for rational urban management and emissions mitigation. Environ Pollut 190:139–149
Chen H-T, Tsutsumi M, Yamasaki K, Iwakami K (2013) An impact analysis of the Taiwan Taoyuan International Airport Access MRT System—considering the interaction between land use and transportation behavior. J Eastern Asia Soc Transp Stud 10:315–334
Chrysoulakis N, Lopees M, Joe RS, Grimmond CSB, Jones BJ et al (2013) Sustainable urban metabolism as a link between biophysical sciences and urban planning: the BRIDGE project. Landscape Urban Plann 112:100–117
Creutzig F, Agoston P, Minx JC, Canadell JG, Andrew RM, Le Quéré C, Peters GP, Shrifi A, Yamagata Y, Dhakal S (2016) Urban infrastructure choices structure climate solutions. Nature Climate Change 6(12):1054–1056
Dodman D (2009) Urban density and climate change. In: Analytical review of the interaction between urban growth trends and environmental changes paper, 1
Fuss S, Canadell JG, Peters GP, Tavoni M, Andrew RM, Ciais P, Jackson RB, Jones CD, Kraxner F, Nakicenovic N, Le Quere C, Raupach MR, Sharifi A, Smith P, Yamagata Y (2014) Betting on negative emissions. Nature Climate Change 4(10):850–853
Großmann K, Bontje M, Haase A, Mykhnenko V (2013) Shrinking cities: notes for the further research agenda. Cities 35:221–225
Gurney KR, Romero-Lankao P, Seto KC, Hutyra LR, Duren R, Kennedy C, Grimm NB, Ehleringer JR, Marcotullio P, Hughes S, Pinceti S, Chester MV, Runfola DM, Feddema J, Sperling J (2015) Climate change: track urban emissions on a human scale. Nature 525:179–181
Haase A, Athanasopoulou A, Rink D (2016) Urban shrinkage as an emerging concern for European policymaking. Eur Urban Regional Stud 23(1):103–107
Hirabayashi Y, Mahendran R, Koirala S, Konoshima L, Yamazaki D, Watanabe S, Kim H, Kanae S (2013) Global flood risk under climate change. Nature Climate Change 3(9):816–821
Hoek G, Beelen R, De Hoogh K, Vienneau D, Gulliver J, Fischer P, Briggs D (2008) A review of land-use regression models to assess spatial variation of outdoor air pollution. Atmos Environ 42(33):7561–7578
Howley P (2009) Attitudes towards compact city living: towards a greater understanding of residential behavior. Land Use Policy 26(3):792–798

Kaido K, Kwon J (2008) Quality of life and spatial urban forms of mega city regions in Japan. In: Jenks M, Kozak D, Takkanon P (eds) World Cities and Urban Form: Fragmented, Polycentric, Sustainable?. Routledge, New York

Kennedy C, Steinberger J, Gasson B, Hansen Y, Hillman T, Havránek M, Pataki D, Phdungsilp A, Ramaswami A, Mendez GV (2009) Greenhouse gas emissions from global cities. Environ Sci Technol 43(19):7297–7302

Koomen E, Diogo V, Dekkers J, Rietveld P (2015) A utility-based suitability framework for integrated local-scale land-use modelling. Comput Environ Urban Syst 50:1–14

Li M, Wu J, Deng X (2013) Identifying drivers of land use change in China: a spatial multinomial logit model analysis. Land Economics 89(4):632–654

Longden T (2015) CO_2 intensity and the importance of country level differences: an analysis of the relationship between per capita emissions and population density. Nota di Lavoro 47.2015, Milan, Italy

Marangoni G, Tavoni M, Bosetti V, Borgonovo E, Capros P, Fricko O, Gernaat DEHJ, Guivarch C, Havlik P, Huppmann D, Johnson N, Karkatsoulis P, Keppo I, Kery V, Broin EO, Price J, van Vuuren DP (2017) Sensitivity of projected long-term CO_2 emissions across the Shared Socioeconomic Pathways. Nature Climate Change 7(2):113

Mindali O, Raveh A, Salomon I (2004) Urban density and energy consumption: a new look at old statistics. Transp Res Part A Policy Practice 38(2):143–162

Mishalani RG, Goel PK, Westra AM, Landgraf AJ (2014) Modeling the relationships among urban passenger travel carbon dioxide emissions, transportation demand and supply, population density, and proxy policy variables. Transp Res Part D Transp Environ 33:146–154

Mora C, Dousset B, Caldwell IR, Powell FE, Geronimo RC, Bielecki CR, Counsell CWW, Dietrich BS, Johnston ET, Louis LV, Lucas MP, McKenzie MM, Shea AG, Tseng H, Giambelluca TW, Leon LR, Haukins E, Trauernicht C (2017) Global risk of deadly heat. Nature Climate Change 7(7):501

Morikawa M (2011) Economies of density and productivity in service industries: An analysis of personal service industries based on establishment-level data. Rev Econ Stat 93(1):179–192

Murakami D, Yamagata Y (2016) Estimation of gridded population and GDP scenarios with spatially explicit statistical downscaling. ArXiv 1610:09041

Muller MR, Middleton J (1994) A Markov model of land-use change dynamics in the Niagara Region Ontario. Canadaian Landscape Ecol 9(2):151–157

Nakamichi K, Yamagata Y, Seya H (2013) CO_2 emissions evaluation considering introduction of EVs and PVs under land-use scenarios for climate change mitigation and adaptation–focusing on the change of emission factor after the Tohoku earthquake–. J Eastern Asia Soc Transp Stud 10:1025–1044

Neuman M (2005) The compact city fallacy. J Plann Edu Res 25(1):11–26

O'Neill BC, Kriegler E, Riahi K, Ebi KL, Hallegatte S, Carter TR, Mathur CR, van Vuuren DP (2014) A new scenario framework for climate change research: the concept of shared socioeconomic pathways. Clim Change 122(3):387–400

Pawlowsky-Glahn V, Buccianti A (2011) Compositional data analysis: theory and applications. Wiley

Rosen S (1974) Hedonic prices and implicit markets: product differentiation in pure competition. J Politi Econ, 34–55

Sato T, Hino S (2005) A spatial CGE analysis of road pricing in the Tokyo metropolitan area. J Eastern Asia Soc Transp Stud 6:608–623

Stewart ID, Oke TR (2012) Local Climate Zones for urban temperature studies. Bull Am Meteor Soc 93:1879–1900

Stewart ID, Oke TR, Krayenhoff ES (2014) Evaluation of the 'local climate zone' scheme using temperature observations and model simulations. Int J Climatol 34:1062–1080

Stocker T (ed.). (2014) Climate change 2013: the physical science basis: Working Group I contribution to the Fifth assessment report of the Intergovernmental Panel on Climate Change (IPCC AR5). Cambridge University Press

Taniguchi M, Ikeda T (2005) The compact city as a means of reducing reliance on the car: a model-based analysis for sustainable urban layout. In: Planning Spatial, Form Urban, Transport Sustainable (eds) Wikkiams, K. Ashgate, Aldershot, UK, pp 139–150

Turok I, Mykhnenko V (2007) The trajectories of European cities, 1960–2005. Cities Int J Urban Policy Plann 24:165–182

Ueda T, Tsutsumi M, Muto S, Yamasaki K (2013) Unified computable urban economic model. Ann Reg Sci 50(1):341–362

Van Schrojenstein Lantman J, Verburg PH, Bregt A, Geertman S (2011) Core principles and concepts in land-use modelling: a literature review. In: Koomen E (ed) Land-Use Modelling in Planning Practice. Springer, Dordrecht, Netherlands, pp 35–57

Voss S (2006) A risk index for megacities. Munchener Ruck, Munich Re Group

Wolfram S (1983) Statistical mechanics of cellular automata. Rev Mod Phys 55(3):601

Yamagata Y, Murakami D, Seya H (2016) A Spatially-Explicit Scenario for Achieving "Wise Shrink" Toward Eco-Urbanism. Articulo-J Urban Res 14

Yamagata Y, Seya H (2013) Simulating a future smart city: an integrated land use-energy model. Appl Energy 112:1466–1474

Yamagata Y, Seya H, Nakamichi K (2013) Creation of future urban environmental scenarios using a geographically explicit land-use model: a case study of Tokyo. Annals of GIS 19(3):153–168

Yoshida T, Tsutsumi M (in press) On the effects of spatial relationships in spatial compositional multivariate models. Lett Spatial Res Sci