



Spatial exploration of rural capital contributing to quality of life and urban-to-rural migration decisions: a case study of Hokuto City, Japan

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Abstract

Globally, urbanization constitutes one of the major underlying drivers of global ecological degradation. Hence, deurbanization, i.e., demographic shift from urban to distant rural areas in a way that increases quality of life (QoL), can be one of the key pathways to address this global challenge. In this study, we investigated the contribution of nature and other types of rural capital to QoL and to people's decision to migrate from urban to rural areas by studying residents in Hokuto City, a popular urban-to-rural migration destination in Japan. An integrated analysis of the 414 responses to a questionnaire survey and open and commercial geospatial datasets representing natural, built, human, cultural, and financial capital revealed the contributions of specific elements of rural capital to people's QoL. These included natural capital (farmland, symbolic natural sites, mountain peak view, lower temperature, and tranquility), built capital (highways, railway stations, shops, and restaurants), and financial capital (employment). Many of these are related to the reasons that migrants, including return and one-way migrants, chose their present home location in Hokuto City, indicating their intention to increase QoL by migration. Particularly, one-way migrant homes were located predominantly on higher up mountain slopes with lower temperatures, higher forest cover, near natural parks, and symbolic natural sites, and yet with easier access to railway stations and employment. These results provide a valuable evidence base for rural spatial planning for increased QoL and attracting migrants that considers ecological–social feedbacks, and hence supports deurbanization.

Keywords Social–ecological systems · Biodiversity · Ecosystem services · Degrowth · Urbanization · Well-being

Introduction

Urbanization affects the global ecological sustainability in several ways. The most direct impact is the land-use/land-cover conversion associated with urban expansion, which often results in a loss of natural/semi-natural ecosystems. Urbanization also has several additional indirect impacts, as urban residents tend to have higher consumption driven by easier and cheaper access to a wide range of goods which are, in many cases, imported from other countries (Elmqvist

et al. 2013; IPBES 2019; Oliveira et al. 2020; Scholes et al. 2018). In consequence, the social–ecological systems in the areas where these goods are produced also experience ecosystem loss and degradation, e.g., by the expansion and intensification of agricultural production (Moran and Kanemoto 2017) and the abandonment of more ecologically sustainable practices of agriculture and land management that were historically used (Kremen and Merenlender 2018).

Therefore, attenuating, or reversing where possible, the urbanization status-quo may be one of the pathways toward social–ecological system sustainability. Such a demographic shift out of urban areas is called, whereas loosely defined, as deurbanization (Eskew and Olival 2018). Deurbanization may fall under the broader degrowth concept, which prioritizes ecological sustainability, justice, and human well-being over economic growth (Asara et al. 2015). Many proposed degrowth practices represent rural lifestyles, such as eating locally or self-produced food, and reconnecting

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with nature through outdoor recreations (Brossmann and Islar 2020; Fitzpatrick et al. 2022). Noting these, we use the term deurbanization in the present study as a demographic shift from urban to distant rural areas focusing on its common properties with degrowth, i.e., ecological sustainability, justice, and well-being. In this respect, our conception of deurbanization is distinct from suburbanization and urban sprawl, which may fall under the currently dominant urbanization trend.

Literature from various sources has highlighted the potential contributions of deurbanization to increasing ecological and social sustainability in Japan. The Japanese government's recent national biodiversity assessment (MOE 2021) identified aggravating trends in three direct drivers of biodiversity loss, i.e., abandonment of agricultural lands and other kinds of management of wildlife and human-mediated ecosystems, invasive alien species, and climate change. Underlying these direct drivers are saturated population and economic growth, as well as heavy reliance on imported food and materials in a globalized economy. Reliance on imports drove reduction in agriculture, forestry, and fisheries production and economy in rural areas, resulting in accelerated rural depopulation. The urban population rate in Japan exceeded 90% in 2010, and is still slightly increasing (The World Bank 2019). Loss of people's direct contact with nature and shifts in lifestyles and values due to urbanization (MOE 2021), as well as increasing ecological footprints of imported goods (Moran and Kanemoto 2017) comprise major indirect drivers of ecological degradation beyond the national boundary. As for social aspects, a future scenario analysis (Hiroi 2019) showed that realizing a shift to a deurbanization pathway by 2029 is imperative for sustainability in various aspects, including national population, finance, welfare services, and infrastructure.

The increase in urban population rate continues to be dominant in Japan, but there is an emerging subtle reverse trend. An increasing number of severely depopulated rural villages have been receiving migrants from urban cities (MIC 2018). A quarter of the population in their 20s living in the three greater urban regions of Japan have reported an interest in migration to rural areas (MLIT 2018). Many of them are attracted to rural areas primarily by the more comfortable climatic conditions, ecological lifestyles, and the availability of fresh and lower price food, but point out the need for decent jobs and income. Further increased interest in rural migration has been reported since the COVID-19 pandemic began (Cabinet Office 2020). This reverse trend is still quite subtle, and not likely to grow easily considering the ongoing nation-wide population decline, but it shows a potential opportunity to accelerate deurbanization by informed and focused actions.

Knowledge on deurbanization from social–ecological system perspectives is fairly limited. In Japan, urban-to-rural

migration has been a human geography and social study subject, and this research typically provides narratives on macro-trends drawing on national demographic data (MIC 2018) or individual cases focusing on policy efforts and their outcomes (Kasami 2022; Odagiri and Tsutsui 2016; Sakuno 2016). These works, however, do not explicitly explain the inherent and unique attributes of rural migration destinations, particularly natural capital, which Gosnell and Abrams (2011) showed to be an important component of individual's decision-making on urban-to-rural migration. The so-called 'four capitals framework' (Costanza et al. 2007) provides an important theoretical ground to explain the process in which natural capital, interacting with built, human and/or social capital, contributes to quality of life (QoL). The framework is well substantiated by empirical studies (Mulder et al. 2006; Panas 2013; Zhang et al. 2018) which, however, have no, or limited if any, view of migration of people who seek a higher QoL in their rural destinations. Hence, the contribution of natural and other types of rural capital, via increase in migrants' QoL, to their migration decision-making remains an important knowledge gap, when we are to better explain deurbanization in a social–ecological systems point of view.

This study aims to explore the natural and other types of rural capital within Hokuto City, Yamanashi prefecture of Japan, that contribute to QoL of the residents, and thus attract migrants to Hokuto City. Hokuto City is an ideal site for the study considering its popularity as a rural migration destination and the availability of relevant information from a precedent study (Takahashi et al. 2021). The subject of our study is not limited to migrants, and also includes native residents, because understanding the differences in the contributors to QoL among the households of different characteristics, e.g., natives and migrants, might provide important policy implications. We use geospatial data and tools to locate natural and other types of rural capital and to quantify the contribution of the residents' accessibility to specific rural capital to QoL. Geospatial computing is a powerful tool to quantify the contribution of various elements of rural capital to QoL because these elements are often spatially distinctive and their contributions to QoL tend to decay with distance (Łaszkiwicz et al. 2022; Olsen et al. 2020). Such a spatially explicit analysis could provide a useful evidence base for rural landscape design that supports a shift to a deurbanization pathway and that considers ecological–social feedbacks.

Materials and methods

Study site

Hokuto City is a rural municipality in Yamanashi Prefecture approximately 158 km west of Tokyo, Japan's capital;

a distance of 2 h by highway or express train. The Hokuto City area covers around 602 km², and comprises primarily forest (75%), farmland (9%), and other land-use types (15%) (MAFF 2015). Hokuto City is renowned for its scenic nature, including views of Mt. Yatsugatake (2899 m) to the north, Mt. Kai-Komagatake (2966 m) to the west, Mt. Mizugaki (2230 m) to the east, and Mt. Fuji (3776 m) to the far southeast, which are all listed in the top-100 scenic mountains of Japan. The city's population was 46,380 (21,806 households) as of December 2021 (Hokuto City 2022). The secondary sector recorded the highest economic gain of approximately 233 billion JPY (64.6%), followed by the tertiary (113 billion JPY: 31.7%) and the primary (5 billion JPY: 1.3%) sectors in 2016 (Yamanashi Prefecture 2018). Employment in the three sectors is disproportional to production, which is highest in the tertiary sector (13,028: 57.9%) followed by secondary (5571: 24.7%) and primary (3597: 16.0%) sectors (MIC 2017). The City is listed as a 'partially depopulating municipality' under the Act on Special Measures for Promotion for Independence for Underpopulated Areas (MIC 2016). Its population, which had been in continuous decline as per the 2045 population projection (NIPSSR 2018a), has trended up over the past few years.

Analytical framework

We developed a basic analytical framework (Fig. 1), which was based on the four capitals' framework (Costanza et al. 2007) and expanded to fit our research purpose. Costanza et al. (2007) postulate that "the ability of humans to satisfy their basic needs comes from the opportunities available and constructed from social, built, human and natural capital". The contributions of different types of capital to fulfilling human needs are expressed by the solid-line arrow, from (b) "access to rural capital" to (a) "human needs fulfillment" in Fig. 1. In addition, the downward solid-line arrows from these two components toward (c) "migration decision" express our proposition that urban-to-rural migration is

driven by people's desire to meet their human needs by improved accessibility to natural and other type of rural capital. Costanza et al. (2007) further noted that the importance of each human need, compared to others, is different among individuals or groups of people. Takahashi et al. (2021) showed such difference among migrants to Hokuto City. Therefore, we considered the effect of (d) "household attributes" in our analyses.

Our conception of rural capital was also based on, but extended from the four capitals framework. In addition to the four capital categories proposed by Costanza et al. (2007), i.e., natural, built, social, and human capital, we added cultural and financial capital drawing on the community capitals framework (Flora et al. 2018). The community capitals framework advocates an approach comprising seven capital types to help foster holistic analysis and action in rural communities, which includes cultural, political, and financial capital, in addition to natural, built, social, and human capital. Whereas financial capital is implicit in Costanza et al. (2007)'s four capitals framework, Vemuri and Costanza (2006) use the UN Human Development Index, which is a composite of per-capita income, life expectancy, education enrollment, and adult literacy, as a surrogate for human and built capital. Likewise, Zhang et al. (2018) use individual and household income to represent built capital. Departing from these usages, we used financial capital as a standalone category as it represents one of the primary factors affecting the migration decision (De-Jong and Fawcett 1981). In addition, we were interested to explore the effect of cultural elements on QoL and migration decisions. Political capital was out of our scope. Hence, we looked at six capital types, i.e., natural, built, social, human, cultural, and financial capital within the Hokuto City territory and referred to them collectively as rural capital.

We gathered data on the four components [(a)–(d) in Fig. 1] using a questionnaire survey, open and purchased spatial datasets, and government statistics. Using these datasets, we analyzed the contribution of an individual's

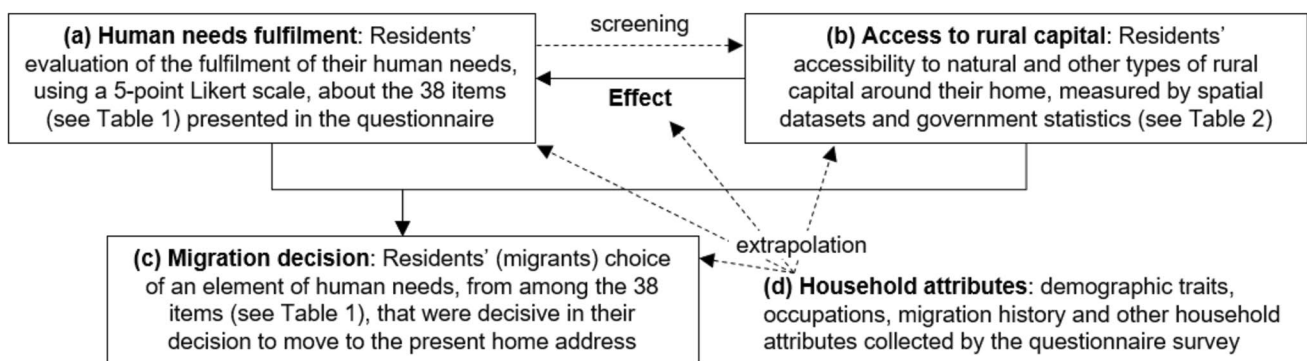


Fig. 1 Analytical framework

accessibility to rural capital to the fulfillment of one's human needs, and finally explored the elements of human needs and the rural capital that were decisive for migrants in choosing their present home address. Sections “[Questionnaire survey](#)”, “[Spatial data and government statistics](#)” and “[Analyses on human needs fulfillment, accessibility to rural capital and migration decisions and on their interactions](#)” provide details of the questionnaire survey, the spatial and statistical data gathered, and the analytical methods used.

Questionnaire survey

We prepared two questionnaire sheet sets—one for native households and the other for migrant households, respectively, containing common and different questions contextualized for the respective type of respondent (see Table A.1 for an English translation of the questionnaire). In the survey, native households were defined as households in which all adult members were born and raised in the current Hokuto City territory, and had never lived outside the area for a year or longer. The rest were determined as migrant households, which were further divided up into return migrants and one-way migrants for analytical purpose: Return migrant households were those with one or more adult members born and raised in the area; and one-way migrant households were those without such an adult member. The operational definitions of natives, return migrants, and one-way migrants as explained above referred to those used by the national authorities but contextualized for our analysis. For example, MIC (2018) and NIPSSR (2018b) define an urban-to-rural migrant household as one which changed its living address from an urban to a rural depopulating municipality between two national census rounds (a 5-year interval in Japan). MIC (2018) defines a return migrant as one who migrated back to the area where they were born and raised, after living in an urban municipality for a certain period for education and/or employment. A migrant to the area where one was neither born nor raised is defined as a one-way migrant. Our operational definitions considered that, in reality, households are usually made up of individuals with different locational backgrounds. We also adopted 1 year of living outside as the cut-off period for dividing natives and return migrants, which was likely to increase sensitivity in our analysis. The job classification used for the survey derived from the Japanese standard classification system (MIC 2014).

The question on human needs fulfillment, comprising 38 sub-questions across six different aspects of life (Table 1), asked respondents to rate their level of satisfaction with each of the 38 human need elements using a five-point Likert scale. These 38 sub-questions derived from the Costanza et al. (2007) list of human needs and was adjusted to our survey context referring to the profiling of migrants to Hokuto City by Takahashi et al. (2021) and Japan's Social Indicators

classification system (MIC Statistics Bureau 2020), and considering their relevance to the six types of rural capital within Hokuto City. The questionnaire had an additional question for return and one-way migrant households to identify the top-five human need elements among the 38 that were decisive in choosing the present home address. We finalized the questionnaire after a pilot test with 12 residents, including natives and migrants, at a workshop held in Hokuto City on 12 September 2019.

We used quasi-random sampling in distributing the survey. We dispatched 2520 questionnaire packets, covering 11.8% of the households in Hokuto City. This number was based on an assumed response rate of 15% and sufficient sample size for statistical analyses with less than 5% sample error and 95% confidence level, in accordance with the guidance provided by Krejcie and Morgan (1970) and Hill (1998). Each packet enclosed a request letter and two questionnaire sheets—one for natives and the other for migrants, respectively—so that respondents could answer the one applicable. The packets were delivered to every seventh house along each street of the entire city area over a period between 20 April and 4 May 2020, based on a commercial housing map provided by Zenrin Co., Ltd. The responses returned no later than 14 May 2020 were used for analyses.

Spatial data and government statistics

We gathered spatial data and government statistics from digital national land information (<https://nlftp.mlit.go.jp/ksj/>), basic map information (<https://fgd.gsi.go.jp/download/menu.php>), Zenrin Building Point Data (ZENRIN 2020), and the Portal Site of Official Statistics of Japan (e-Stat: <https://www.e-stat.go.jp/en>). From these sources, we extracted spatial data and statistics that were semantically relevant to the 38 human need elements as well as to the six types of rural capital—referring to the definitions of natural, built, social, and human capital by Costanza et al. (2007) and cultural and financial capital by Flora et al. (2018). Among the six capital types, however, social capital was removed from the spatial analyses, because the spatial data that explicitly represent social capital were not identified from the above sources.

An initial processing of these datasets generated 27 spatial data items (Table 2). These mostly derived from simple extraction of relevant elements from the original sources, except for three numeric data items, i.e., mountain peak view surface data, employment point data, and noise-level surface data, which required additional calculations. The mountain peak view surface data, proposed as a proxy for scenic beauty, was measured by the visibility of four prominent peaks around Hokuto City (Mt. Akadake of the Yatsugatake range, Mt. Kai-Komagatake of the Japanese Southern Alps range, Mt. Mizugaki, and Mt. Fuji) at each spatial location. This was calculated through viewshed analysis using

Table 1 A list of 38 human need elements relating to six aspects of life

Aspects of life	Human needs element
Work and employment	1. Availability of places, materials, and the environment for work 2. Enabling conditions for a new challenge 3. Contribute to local community through work 4. Unique business chance and/or network of collaborators 5. Urban access 6. Comfortable workplace 7. Work-life balance 8. Prestigious or influential job 9. Income 10. Low business cost
Housing and lifestyles	11. Comfortable climate or clean air 12. Clean water 13. Local food 14. Low housing cost 15. Ideal house 16. Renewable energy 17. Scenic beauty 18. Tranquility and natural soundscape 19. Ideal lifestyle 20. Mobility 21. Shopping and eating out 22. Low living expenses 23. Government subsidy or tax exemption 24. Security
Child raising and education	25. Time with family 26. Community support to child raising 27. Outdoor activities for children 28. Public support/facility for child raising and/or education 29. Good schooling
Medical and health care	30. Medical services (public facility/support for health and elderly care) 31. Natural environment to support medical treatment and rehabilitation
Culture, leisure and learning	32. Unique local culture 33. Public facility/support for learning and sports 34. Space for sports and outdoor recreations
Family and community relations	35. Nearness of family and friends 36. Participation in and contributions to the local community 37. Stimulating people 38. Sense and identity of place

the digital elevation model, following the method used in Vukomanovic et al. (2014). The employment capacity point data give the estimated number of employees at individual business locations. Specifically, the total number of employees in each district from the 2014 Economy Census data was distributed to the individual office locations within the district in proportion to the office floor area provided by the Zenrin Building Point Data. The noise-level surface data were generated from the national road traffic census data (MLIT 2015b) and guided by Watanabe et al. (2009) which provides a simple method to simulate a road traffic volume to meet the Japanese environmental quality standard on noise annoyance. It may be counter-intuitive to use noise level, among others, as a parameter of natural capital: our proposition was to use it as an inverse natural capital parameter considering the increasing natural soundscape pleasantness with reduced human-made noise (Levenhagen et al. 2021).

Analyses on human needs fulfillment, accessibility to rural capital, and migration decisions and on their interactions

Our analyses took the following five steps to unpack each of the four components and their interactions illustrated in the analytical framework (Fig. 1).

First, we measured the level of the fulfillment of the respondents' human needs (Fig. 1a) by their evaluation of the 38 items (Table 1) in the questionnaire. To understand the overall tendency among the residents, we used principal component analysis (PCA) and cluster analysis to reduce the dimensions of the variables, and thereafter tested the effects of the respondents' household attributes on the reduced variables using ANOVA and the Bonferroni-type multiple comparison [shown by the dotted-line

Table 2 Spatial data and government statistics used for geospatial analyses

Feature name	Capital type	Source	Data title (code, where assigned)	Data element used for analysis (code, where assigned)	Year	Processed data type	Unit
Farmlands	Natural	Digital National Land Information	Land use 100 m mesh (L03-b-16)	Rice paddies (100)	2016	Surface, cat. ^a	m ²
				Other agricultural land (200)	2016	Surface, cat	m ²
Forest	Natural			Forest (500)	2016	Surface, cat	m ²
Natural parks	Natural		Natural parks (A10)	All	2015	Surface, cat	m ²
Temperature	Natural		Climate 1 km mesh (G02)	Annual mean temperature (53)	2012	Surface, num. ^b	°C
Streams	Natural		Streams (W05)	All	2008	Line, cat.	m
Symbolic natural sites	Natural		Symbolic natural/geological sites (P19)	All	2012	Point, cat.	Number of points
Water	Natural			Canyon, waterfall or spring (6-601, 610, 903)	2012	Point, cat.	Number of points
Farmers' markets	Natural		Local business facility (P24)	All, incl., on-farm markets/restaurants and experience farm/facility	2012	Point, cat.	Number of points
	Natural		Tourism resource (P12a)	Shops, restaurants and other facility (7-5~6)	2014	Point, cat.	Number of points
Outdoor recreations	Natural			Sports and recreation sites (7-4)	2014	Point, cat.	Number of points
Local events	Cultural			Natural, cultural or historical events (7-1~2)	2014	Point, cat.	Number of points
Hot springs	Natural			Hot spring and healthcare facility (7-3)	2014	Point, cat.	Number of points
Cultural heritages	Cultural		Cultural heritage (P32)	All, incl., tangible/intangible/folkloristic heritages, monuments, cultural landscapes/buildings	2014	Point, cat.	Number of points
Schools	Human		Schools (P29)	All, incl., primary, junior high and high schools and colleges	2006	Point, cat.	Number of points
Medical facility	Built		Hospitals and clinics (P04)	All, incl., hospitals, general clinics and dentists	2020	Point, cat.	Number of points
Cultural facility	Built		Cultural facility (P27)	Museums, archives, libraries, aquariums, zoos and botanical gardens (4-03001 to 03005)	2006	Point, cat.	Number of points
Sports facility	Built			Sports field/facility (4-03101 to 03110)	2006	Point, cat.	Number of points

Table 2 (continued)

Feature name	Capital type	Source	Data title (code, where assigned)	Data element used for analysis (code, where assigned)	Year	Processed data type	Unit
Bus stops	Built		Bus stops (P11)	All	2010	Point, cat.	Number of points
Railway stations	Built		Railway stations (S12)	All	2020	Point, cat.	Number of points
Highway gates	Built		Highway data (N06)	Entrance gates (N06_019/1, 2)	2020	Point, cat.	Number of points
Mountain peak view	Natural	Basic map information	Digital elevation model 10 m mesh	All	2021	Surface, num.	Number of peaks
Shops and restaurants	Built	Zenrin Building Point Data	Zenrin Building Point Data	Restaurants, shops and discount stores	2020	Point, cat.	Number of points
Shop/restaurant floor area	Built			Floor area of restaurants, shops and discount stores	2020	Point, num.	Number of points
Enterprises	Financial			Office	2020	Point, cat.	Number of points
Office floor area	Built			Office floor area	2020	Point, num.	m ²
House floor area	Built			Resident house floor area	2020	Point, num.	m ²
Employment capacity	Financial	e-Stat ^c	2014 Economy Census Basic Survey district statistics	Number of employees	2014	Point, num.	Person
Noise level	Natural	National Road Traffic Census	Road traffic table-Yamanashi Prefecture	24 h traffic total, vehicle velocity average and the proportion of cargo vehicles	2015	Surface, num.	dB

^acat. categorical data

^bnum. numeric data

^cPortal Site of the Government Statistics of Japan

arrow from component (d) to (a) in Fig. 1]. This procedure followed Hinkin (1998) and Carifio and Perla (2008).

Second, we quantified the respondents' accessibility to different types of rural capital (Fig. 1b) through geospatial analysis. On a digital map, the home address of a respondent was represented by an aggregation of the 100 m square grids that correspond to the settled area of the ward of the respondent's home address (acquired from the questionnaire). This involved generating 100 m grid cells from the e-Stat ward-level administrative boundary polygons, extracting the grid cells that contained one or more resident house point(s) provided by the Zenrin Building Point Data (ZENRIN 2020), merging the settled cells in each ward, and finally matching the ward-wise merged settled cells with the respondent's home address. It was necessary to extract only settled area in each ward to obtain sufficient spatial resolution of resident home locations, considering a high coverage of unsettled lands, particularly mountains and forests, in many wards in Hokuto City.

The measurement of accessibility was taken in seven different distance ranges, i.e., within settled grids of each ward, as well as within the buffer polygons of 250 m, 500 m, 1 km, 2 km, 4 km, and 8 km radii from the external edge of the settled grids. Accessibility to the elements of rural capital represented by categorical surface, line, or point data, among the 27 elements (Table 2), was measured by their density within the seven distance ranges, producing area coverage rate (%), total length per area (m/m²), and number of points per area (/ha) parameters, respectively. Accessibility to the elements represented by numeric surface data, except for temperature and noise level, was measured by the average of the grid cell values within the seven measurement ranges. Likewise, accessibility to the elements represented by numeric point data, except for house floor area, was measured by totaling the point values within the seven measurement ranges, respectively, which then was divided by the area of the respective measurement ranges for standardization. The temperature,

noise level, and house floor area values were averaged only within the settled grids of each ward, because these values matter for a resident only at one's home. The measurement of the residents' accessibility to the 24 rural capital elements, excluding these three from among the 27, in different distance ranges from each ward, aimed to enable an analysis sensitive to the rural capital elements outside the settled area of each ward that potentially contribute to human needs fulfillment and that have varied spatial patterns. The need for applying different distance ranges was also because varied decay distances of welfares are derived from natural and built capital in different contexts as shown by earlier studies (Cho et al. 2011; Eom et al. 2018; Tammi et al. 2017). This procedure produced 171 variables, in total, of the accessibility to the 27 rural capital elements by residents in each ward.

Third, we generated a longlist of the combinations of rural capital and potentially relevant human need elements, which then was screened to produce a shortlist of combinations of stronger relevance [shown by the dotted-line arrow from the component (a) to (b) in Fig. 1]. To generate the longlist, each of the 27 rural capital elements was matched with all semantically relevant human need elements from among the 38 items listed in Table 1. From the longlist, the combinations with the Spearman's correlation coefficient of no less than 0.2, indicating weak correlation (Akoglu 2018), in at least one distance range were selected. Regarding each of the selected combinations between the 24 rural capital elements (with the accessibility measurement in seven distance ranges) and human need elements, one distance range that produced the strongest correlation was chosen. The remaining combinations after the above screening process formed the shortlist. We applied this screening process to identify nuanced biophysical indicators, which Roman and Thiry (2016) pointed out as a challenge in the precedent studies.

Fourth, in the shortlisted combinations, we assessed the contribution of the accessibility to rural capital in a specific distance to human needs fulfillment using ANCOVA [expressed by the solid-line arrow from the component (b) to (a) in Fig. 1]. The ANCOVA controlled the household attributes that were tested as significant in the first step to explain variance in the level of the fulfillment of different human needs among the respondents. In addition, an ANOVA of rural capital accessibility among respondents was conducted to help interpret the ANCOVA results.

Fifth, we identified the human need and rural capital elements that were decisive in the migrants' decision to move to the present home address in Hokuto City [shown by the downward solid-line arrows from components (a) and (b) to (c) in Fig. 1]. This analysis matched the respondents' choice of a human need element, from among the 38 elements presented in the questionnaire, that were decisive in making

a migration decision, with the results of the former step on the links between rural capital and human needs fulfillment.

We used QGIS version 3.10 (QGIS.org 2020) for geocomputing and R version 4.0.3 (R Core Team 2021) with the tidyverse package (Wickham et al. 2019) for statistical analyses and graph drawing.

Results

Summary of survey respondents

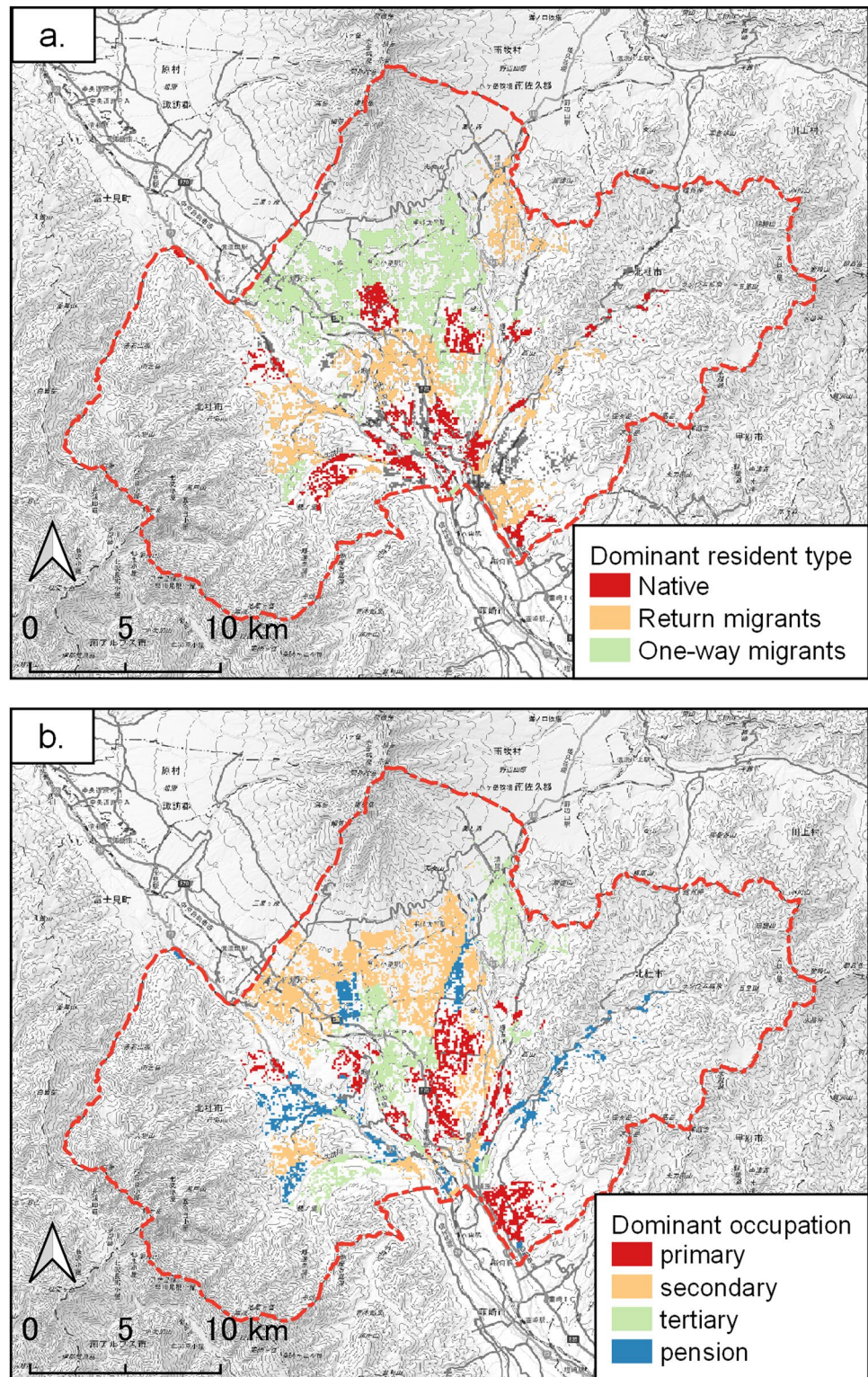
The number of questionnaires returned was 414, which is 16% of the questionnaires distributed and 2% of the households registered to the Hokuto City municipal office as of January 2021. Summary statistics on the respondent household attributes are presented in Table A.2. This includes basic data with important implications, e.g., distance from one's home to work location where 63 respondents (15% of all valid responses) identified their work location at home. The data also show migrants' housing type, where 129 (45% out of all migrant households) built new houses on purchased or rented properties. Further, results using Pearson's Chi-squared test showed a statistically significant association between the respondents' home ward and their migration history ($X^2 = 173.88$, $df = 112$, $p = 1.63e^{-4}$) and occupation sector ($X^2 = 357.03$, $df = 280$, $p = 1.25e^{-3}$), among other household attributes, indicating a spatial difference in home areas between households of these two attributes (Fig. 2).

Human needs fulfillment

The 38 sub-questions on human needs fulfillment obtained 314 valid answers. A PCA of the Likert scale scores of these sub-questions identified seven principal components with eigenvalues not less than 1, and the cumulative contributions of the seven eigenvalues to variance in the 38 raw variables was 66.79%. Then, cluster analysis performed on the eigenvectors obtained from the 38 raw variables against the seven principal components identified 13 clusters at a Euclidean distance of 0.464, which was an appropriate resolution to represent different rural capital types (Fig. 3). Among the 13 human need clusters, natural amenity (cluster 4, natural capital) had by far the highest mean score. In contrast, income or prestigious/influential job (cluster 3, financial capital) had the lowest score, followed by convenience of life (cluster 7, built capital).

ANOVA and the Bonferroni pairwise t test of the difference in the mean scores of the 13 human need clusters between households with different traits identified a significant difference between native, return, and one-way migrant households in five clusters (Fig. 3). One-way

Fig. 2 Dominant household groups in each ward regarding **a** migration history and **b** occupation of primary income earner. The color of the settlement area represents the relative dominance of household groups of a different migration history and **b** different forms of occupation of the primary income earner within each ward. The relative dominance was identified by three steps to account for the difference in sample size between wards and between groups: (1) calculating the proportions of the households falling under respective groups within each ward, (2) transforming these proportions into ranks between wards for each group, and (3) isolating the group that ranked the highest within each ward



migrants were more satisfied than return migrants with natural amenity (cluster 4) but less with housing costs (5). Native and return migrant households were more satisfied with their engagement with family, friends, and local community (clusters 12 and 13) than one-way migrants.

The level of fulfillment of health-related needs (cluster 10) was higher among natives than one-way migrants. Likewise, the households with children were more satisfied with income (cluster 3), lower living expenses (8), outdoor space, schools, and community support for children (9),

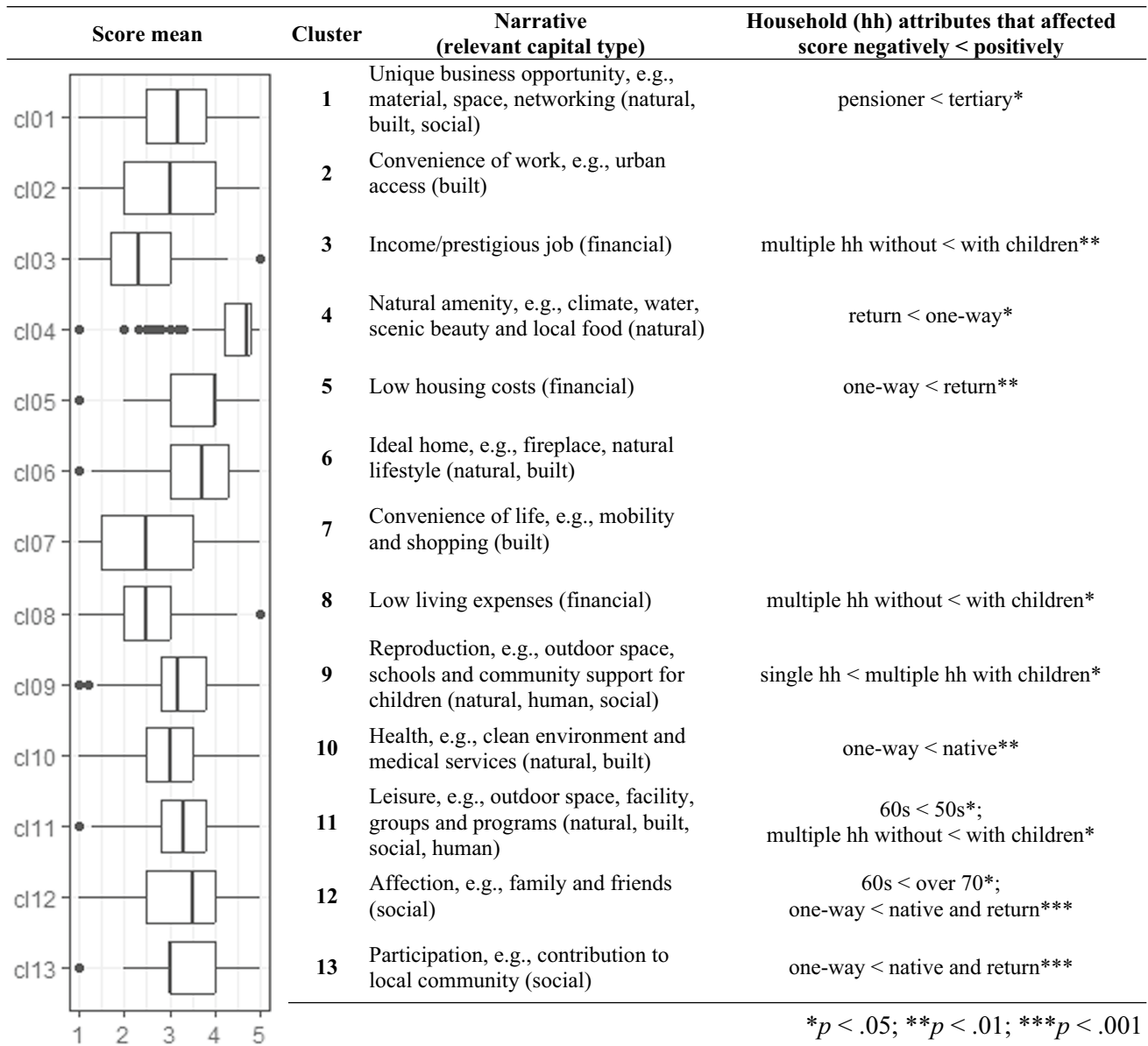


Fig. 3 Distribution of mean score of the 13 human need clusters and influential household attributes

as well as leisure opportunities (11) than those without children.

The contribution of rural capital accessibility to human needs fulfillment

The initial longlist contained 1309 combinations of human need and rural capital elements in different distance ranges. From the longlist, a shortlist of 71 combinations was obtained after screening out the combinations with weak correlation ($R^2 < 0.2$ in all the measurement ranges) and extracting the measurement range with the strongest correlation from each of the remaining combinations. Finally,

ANCOVA identified 17 combinations concerning 13 rural capital elements in which better accessibility to each rural capital element in a specific distance range from the respondents' home significantly contributed to fulfilling their human needs (Table 3). Maps of the spatial pattern of each rural capital element produced in this process were presented in the supplementary material (Figure A.1).

The analysis revealed the difference in these contributions between native, return, and one-way migrant households and between households with different occupation types of the primary income earner. The needs of one-way migrant households, as compared to native households, for leisure opportunities and for the realization of their ideal lifestyles

Table 3 ANCOVA results on the contribution of rural capital accessibility to human needs fulfillment with household attribute covariants

Rural capital	Human needs	Range	Slope	Covariant	Residual SE	Multiple R ²	F value	Figure 4 ^a
Farmlands	Local food	4 km	Mig: native	Mig: one-way	0.974	0.034	2.633*	N1
	Business resource	100 m	Job: primary	Job: Un-employed	0.974	0.034	2.91**	–
Forest	Business resource	100 m	Job: primary	Job: pension	1.279	0.104	2.805**	–
	Natural parks	2 km	Mig: native	–	0.993	0.058	4.57***	–
Symbolic natural sites	Sports/outdoor recreation	8 km	Mig: native	Mig: one-way	0.988	0.066	5.253***	N2
	Comfortable work space	8 km	Job: primary	Job: tertiary	1.215	0.109	2.881**	–
Mountain peak view	Scenic beauty	500 m	Mig: native	–	0.695	0.04	3.209**	N3
	Ideal lifestyle	100 m	Mig: native	Mig: one-way	0.993	0.077	6.092***	N4
Mean temperature	Tranquility	100 m	Mig: native	–	0.721	0.067	5.505***	N5
	Noise level	1 km	Mig: native	–	1.338	0.037	2.355*	B1
Highway gates	Urban access	250 m	Mig: native	–	1.325	0.038	3.055*	B2
	Mobility	4 km	Mig: native	–	1.331	0.048	3.047*	B3
Railway stations	Urban access	2 km	Mig: native	–	1.199	0.066	5.467***	B4
	Shops and restaurants	100 m	Mig: native	Mig: return	1.029	0.073	6.086***	B5
Medical facility	Medical services	100 m	Mig: native	Mig: return	0.975	0.091	7.366***	–
	Sports facility	100 m	Mig: native	Mig: return	1.098	0.048	2.675*	F1
Sports facility	Sports/outdoor recreation	2 km	Mig: native	–	1.002	0.041	2.387*	F2
	Prestigious/influential job	2 km	Mig: native	–	1.002	0.041	2.387*	–
Employment capacity	Prestigious/influential job	2 km	Mig: native	–	1.002	0.041	2.387*	–
	Income	2 km	Mig: native	–	1.002	0.041	2.387*	–

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$ ^aColumns “Fig. 4” and “Fig. 5” present the label of the respective data plots (sub-diagrams) in Fig. 4

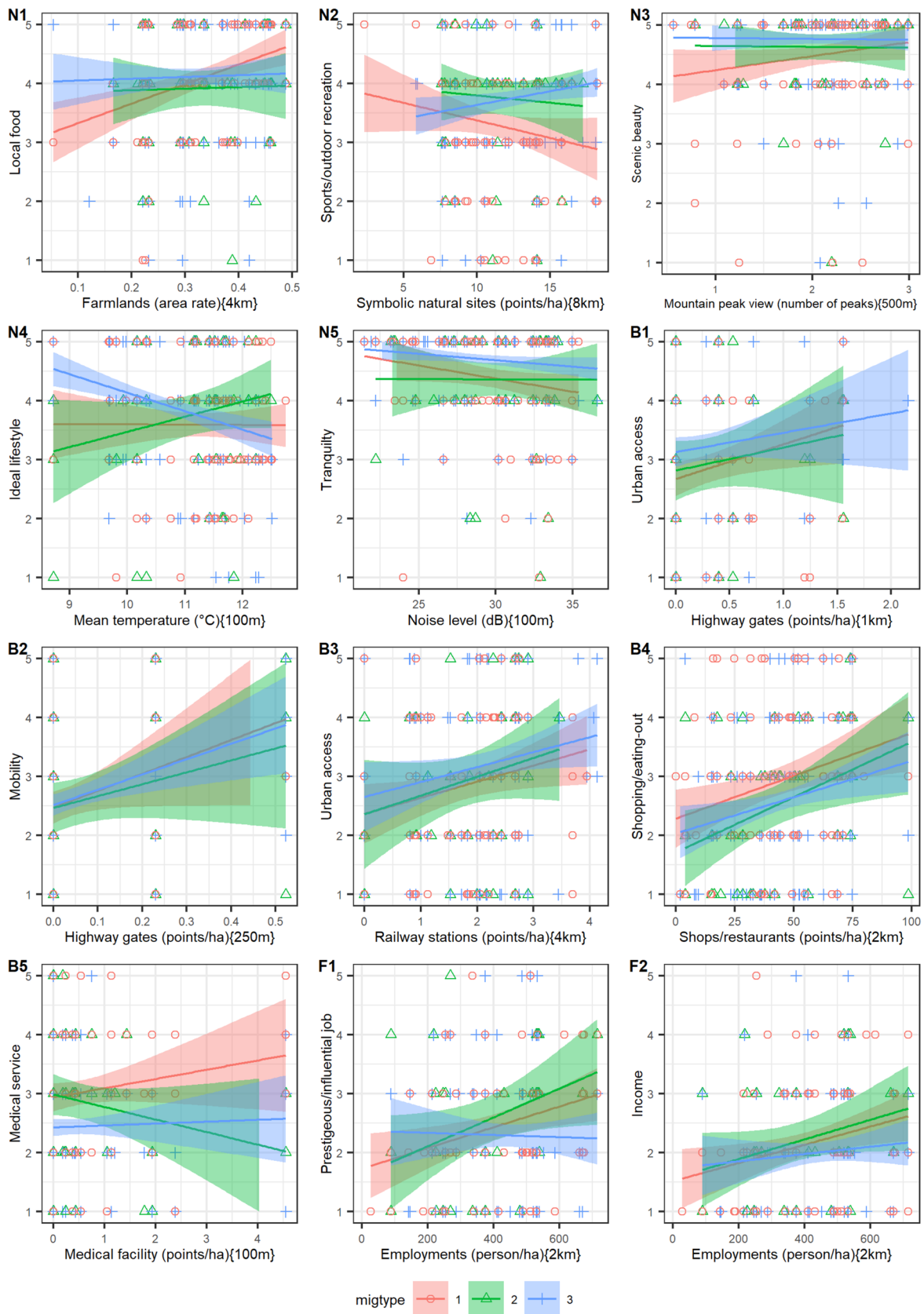


Fig. 4 Contribution of rural capital accessibility to human needs fulfillment. Legend: migtype (migration type); 1: native residents; 2: return migrants; and 3: one-way migrants. Sub-diagram labels (N1–5, B1–5, and F1–2) correspond to the results of ANCOVA presented in Table 3, with “N”, “B”, and “F” representing natural, built, and financial capital, respectively. Horizontal axis of each sub-diagram shows the accessibility to each rural capital element, with the unit of measurement in round brackets “()” and the measurement range in curly brackets “{ }”. Vertical axis shows the level of the fulfillment of each human need element which was evaluated by the respondents using a five-point Likert scale in the questionnaire

were better met in the areas with the higher accessibility to symbolic natural sites and with lower temperatures, respectively (Fig. 4 N2, N4). Native households were more satisfied with rich local food and scenery in areas with higher farmland coverage and better mountain views, respectively (N1, N3). Lower traffic noise, proximity to highway gates and railway stations, and a better accessibility to stores and employment capacity unanimously contributed to meeting the human needs of native, return, and one-way migrant households (N5, B1–4, F1–2).

The complementary ANOVA tested the variation of rural capital accessibility between the respondents in different groups concerning the two household attributes that were shown as significant, in the section “[Summary of survey respondents](#)”, to explain their settlement patterns, i.e., migration history and occupation groups. The analysis revealed a significant difference in the accessibility to six, among the 13, rural capital elements between native households and return and one-way migrant households (Fig. 5). One-way migrant households tended to live in the wards nearer natural amenities than native and return households, e.g., with higher forest cover, near natural parks and symbolic natural sites, or on higher up mountain slopes where temperatures are lower. Their home locations were also in the areas with a better accessibility to key built and financial capital elements, i.e., railway station and employments. The analysis also showed difference in the accessibility to three capital elements between the households in different occupation groups. Home location of tertiary sector workers and pension households, among others, tended to have higher forest cover, be nearer natural parks, and on higher up mountain slopes with lower temperatures.

Migration decision

The questionnaire identified key human need elements that were decisive for return and one-way migrant households in choosing their new home location (Fig. 6). More than a quarter of them identified scenic beauty, climate, tranquility, and water as the key qualities for choosing their present home address. Linking these elements to the rural capital elements, referring to Fig. 4, suggests key elements of rural capital that

have attracted migrants to Hokuto City. These were lower temperatures on higher up mountain slopes providing a comfortable climate and enabling ideal lifestyles; distance from high-traffic roads providing tranquility; proximity to farmlands for local food supply; symbolic natural sites providing sports and outdoor experiences; as well as highway gates and railway stations enabling better urban access.

Discussion

To address our primary research aim, we first discuss the pathway in which rural capital contributes to QoL and thereby to migration decisions (“[Contribution of rural capital to QoL and migration decisions](#)”). This draws on a synthesis of the results of the five-step analyses presented in the former section, and characterizes rural capital in accordance with our capital typologies, i.e., natural, built, financial, social, human, and cultural capital. The discussion also highlights our findings in measuring accessibility to various rural capital elements that have different spatial patterns and ways to influence people. We then clarify methodological constraints in the present study and the potential ways to overcome these constraints (the section “[Methodological constraints](#)”). The section ends with the social–ecological system implications of deurbanization from our results (the section “[Social-ecological system implications of deurbanization](#)”).

Contribution of rural capital to QoL and migration decisions

Overall, the rural capital elements we tested as effective in increasing QoL agreed with the reasons for the migrants’ choice of living in Hokuto City, confirming their aim to increase QoL by migration. Further, our results confirmed the contribution of a set of indicative, but not exhaustive, geospatial metrics of natural, built and financial capital to higher QoL.

Natural capital

The natural capital metrics found to be contributing to migrants’ QoL were accessibility to symbolic natural sites providing leisure opportunities, lower temperatures supporting ideal lifestyles, and lower noise levels allowing tranquility in life. These three natural capital elements agree with the top three reasons migrants chose Hokuto City, i.e., scenery, climate, and tranquility. This well explains that one-way migrants are found living in areas higher up on mountain slopes that have a higher forest cover, better accessibility to symbolic natural sites, and lower temperature (Fig. 5).

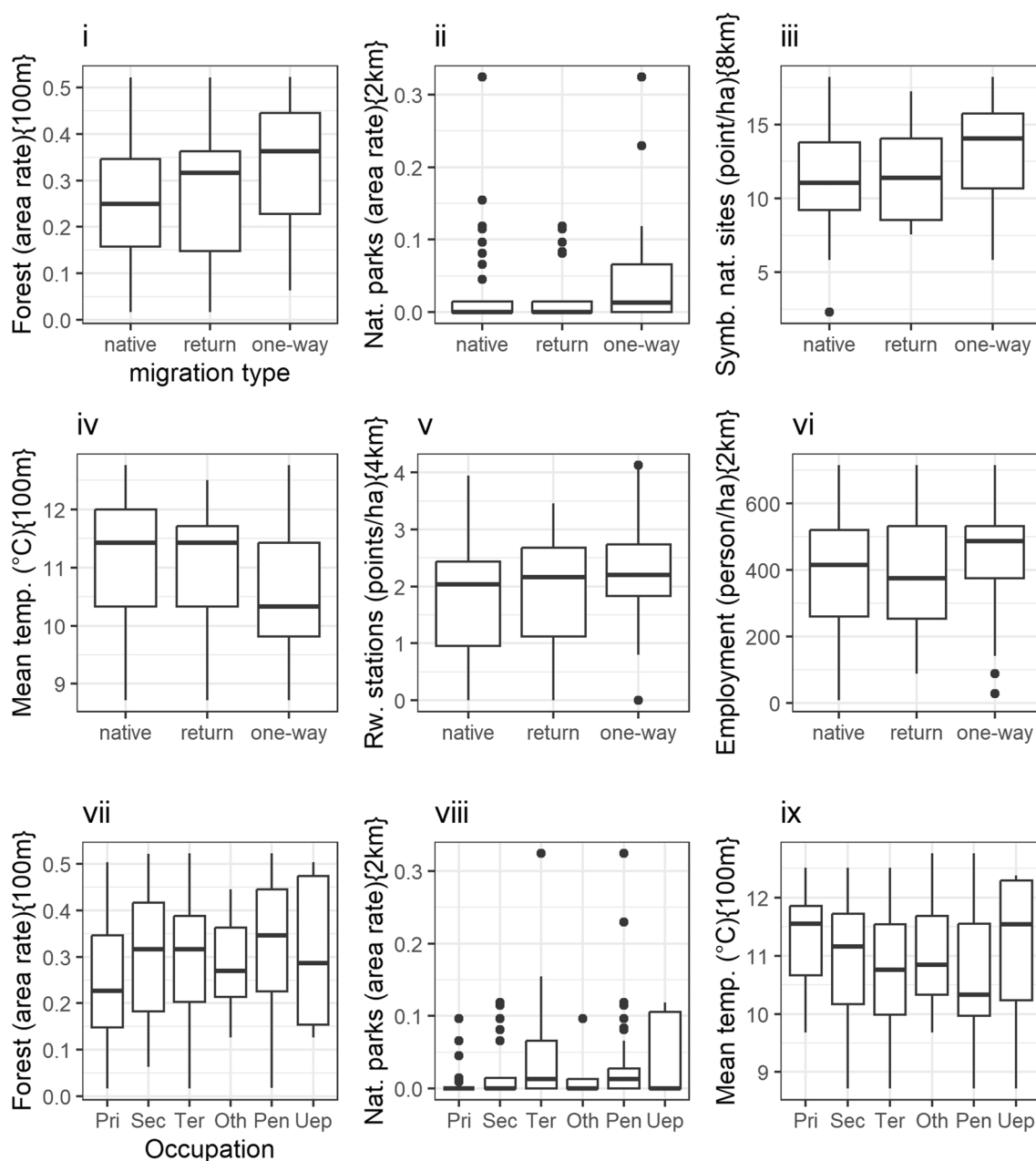


Fig. 5 Variation in accessibility to rural capital between households with different migration history (i–vi) and occupation of primary income earner (vii–ix). Vertical axis of each sub-diagram shows the accessibility to each rural capital element, with the unit of measurement in round brackets “()” and the measurement range in curly brackets “{ }”. In diagrams vii–ix, the horizontal axis label “Pri”

indicates the primary sector; “Sec” the secondary sector; “Ter” the tertiary sector; “Oth” other unclassified sector; “Pen” pension; and “Uep” unemployed. *F*-statistics for the nine sub-diagrams were: (i) 14.899***; (ii) 4.278*; (iii) 12.989***; (iv) 19.134***; (v) 8.246***; (vi) 6.511***; (vii) 2.491*; (viii) 2.544*; and (ix) 3.023* (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$)

Further, two natural capital metrics that contributed solely to the natives’ QoL were found, i.e., farmlands providing food, and better views of mountain peaks constituting scenic beauty. The former could be explained by the engagement of a relatively high proportion of native households in farming. Non-market food sharing with neighbors, which is widely practiced in Japanese rural communities

(Kamiyama et al. 2016), could be another reason, implying potential interaction between social and natural capital. The latter might have derived from better visibility of mountain peaks from natives’ homes, which tend to be located in the areas with high farmland coverage. They also might have a sense of place (Díaz et al. 2018) since their childhood, due to the unique views of mountains in their locality. In

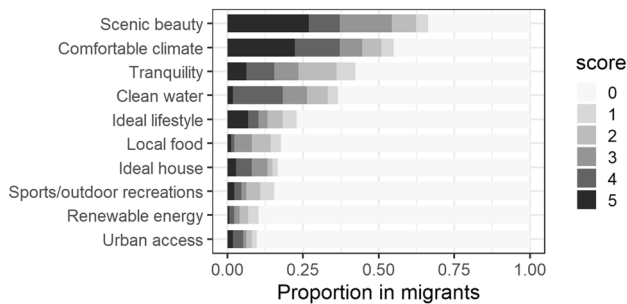


Fig. 6 Top-10 elements of human needs identified by migrants as the primary reason for choosing their present home address when migrated

contrast, one-way migrants might only have constricted views of mountains from their home surroundings, which largely comprise forests. Considering the known contribution of the view of complex terrain and forests to migrants' home location (Vukomanovic et al. 2014), the presence of views encompassing greenery in migrants' home surroundings, rather than mountain views, could better explain the consistently high satisfaction with scenic beauty expressed by the migrants in our results (Fig. 4).

Built capital

The built capital metrics that were found to contribute to QoL, non-selectively among natives and migrants, were the accessibility to highway gates, railway stations, and shops and restaurants. Among these, the importance of access to railway stations for migrants is more evident from the relative proximity of their homes to railway stations than natives (Fig. 5). Our analysis did not detect the contribution of the proximity to bus stops to better mobility. Presumably, this is due to infrequent bus services and thus less reliance of the residents on buses, particularly in areas distant from railway stations.

Financial capital

Employment capacity, as a metric of accessibility to financial capital, contributes to QoL of both native and migrant households. The effective distance range of 2 km (Table 3) is relatively short as compared to the mean commuting distance in Japanese rural municipalities, which is approximately 30 min (MLIT 2015a) or 20 km assuming a 40 km/h car trip. A certain proportion of respondents indicated zero commuting time (see the section “[Summary of survey respondents](#)” and Supplementary Table A.2), presumably indicating their engagement in home business, which might explain the overall short commuting distance. As home businesses usually do not require large built structures such as office buildings

or manufacturing plants, this shows the appropriateness of our attempt to single out financial capital from built capital, (unlike Vemuri and Costanza 2006; Zhang et al. 2018), and to represent it by employment capacity.

The effect of the COVID-19 outbreak since 2020 onward, which brought about rapid and widespread uptake of teleworking, on this result was presumably limited, because the analysis relied on the enterprise location registration data as of 3 August 2020. It is unlikely that the data reflected the telework shift, because moving enterprise registration location would not always be necessary for teleworking, and even when moved, would require a longer time lag to be captured in the enterprise registration data. The results, however, imply that the proximity between home and work locations, as a result of the uptake of teleworking, contributes positively to QoL in rural areas. Many companies in Japan have continued teleworking arrangements for employees even after the COVID-19 risk downgrading (Pasona Inc. 2023), which is likely to encourage rural life of employees and to help increase their QoL.

Other rural capital

No geospatial surrogate for social, human, and cultural capital was identified from the scope of our data gathering. Nevertheless, relating to social capital, we detected a higher fulfillment of affection (cluster 12, Fig. 3) among native and return households, which is linked to the proximity of family members and friends. Strong social capital and its contributions to well-being are found in many Japanese rural communities (Shiga University and ESRI 2016). Social capital is known to play an indispensable role for migrants in their migration process and establishment (Odagiri and Tsutsui 2016). Therefore, identification of a spatially explicit surrogate for social capital remains an important subject for future studies, which might include natural or other capital elements that provide foundations for building social capital, such as green spaces that facilitate social interactions (Dasgupta et al. 2022; Jennings and Bamkole 2019).

Metrics of rural capital accessibility

The results also show different distance ranges within which rural capital contributes to QoL depending on the type of capital and the ways people interact with these. This agrees with Olsen et al. (2020) which clarified unique distance decay parameters for different ecosystem services. Our results show roughly three groups of rural capital that have different distance ranges in the decay of their contribution to QoL. The first group, with the shortest decay distance in a 500 m radius or less, includes farmland for livelihood, temperature, and low noise level for comfortable living, and mountain views for scenic beauty. These types of capital

contribute to individual QoL through one's daily exposure to these elements at home, and presumably in a short walk from home considering the use of a 500 m range as a short walking distance range in an urban planning literature (Eom et al. 2018). The second group, with a medium decay distance of 1–4 km, includes employments supporting income and status, shops, and restaurants for convenience in life, farmland for food, and highway gate for easy urban access. Contribution to subsistence within a short-trip distance characterizes these types of rural capital. The third group, with the longest decay distance of around 8 km, includes symbolic natural sites that contribute to leisure satisfaction, presumably through occasional recreation visits.

Methodological constraints

The interpretation of these results, however, requires noting the following three major methodological constraints. The first is the bias in the available open and commercial geospatial data, which tended to represent tangible capital assets, such as natural, built, and financial capital, but not intangible capital assets, e.g., social, human, and cultural capital. Each data item differs in terms of type and resolution of data between one another, which might have limited the veracity of comparing the contribution of different rural capital elements to QoL.

Second, a limited number of and bias in the questionnaire respondents, as well as the processing of the responses might have affected the results. Whereas the number of responses to the survey was sufficient for the analyses on the whole sample, reduced statistical reliability of the results was unavoidable particularly from the analysis with a higher number of group breakdowns, e.g., age groups and occupation groups. Biases might also have derived from different responses rates among groups, e.g., fewer responses from the younger, working generations than from the senior generations. The resolution used to locate the respondents' home, i.e., by the union of 100 m square grids of settled areas in each ward, might also suffer in terms of accuracy. We could not attain a higher resolution with the available geospatial data to project the respondents' home address to a GIS map while also protecting personal information.

Third, the two-step screening process to short list geospatial surrogates for rural capital might also have affected the reliability of measuring the influence of each capital in terms of distance. The use of Spearman's correlation coefficient, applied collectively to all sample households, to identify the most effective distance from among the seven distance ranges might have neglected a distance range that more strongly effected the satisfaction of human needs of specific household groups.

Whereas the above three constraints suggest the need to further improve the balance and reliability of our model, our

finding of the contribution of the 13 geospatial surrogates of natural, built, and financial capital to QoL remains valid. A set of standardized geospatial indicators that equally represent different capital types might enable a more balanced and reliable evaluation of the contribution of rural capital to QoL. Future studies might also benefit from a more rigorous and systemic process to optimize the indicator sets.

Social–ecological system implications of deurbanization

Our finding regarding the specific elements of natural capital that contribute to urban-to-rural migration decision-making demonstrates an important feedback pathway from nature to human behavior, which was known to be an important knowledge gap in the social–ecological system literature (IPBES 2019). However, we did not investigate the reverse pathway that motivated the present study, i.e., the potential contribution of urban-to-rural migration to the sustainability of social–ecological systems.

In general, an increasing number of migrants can hamper nature when it comes with new land and infrastructure development. This may or may not be true within the geographical and temporal scope of our study. Nearly half of migrants in our sample had built new houses when they migrated (Supplementary Table A.1). These houses, however, were likely to have been constructed on the pre-existing city infrastructure (e.g., the existing houses were demolished and new houses constructed), as land and infrastructure development had peaked out in Hokuto City in the 1990s toward the end of the Japanese bubble economy which drove a second-house boom, and considering declining total city population since 2004 onward (Hokuto City 2018). Change in the lifestyles of migrants and its ecological consequences could be another potentially important aspect to be assessed. Filling these knowledge gaps is necessary for a more comprehensive understanding of the feedback loop between nature and human behavior in social–ecological systems in the deurbanization context.

Conclusions

Globally, urbanization has significant direct and indirect impacts on social–ecological systems. Deurbanization plans and policies can help address these impacts, but it is important to better understand urban residents' desires for rural migration (e.g., in terms of improving their QoL) to support these policies. The present study shows the contribution of the accessibility of residents to specific elements of natural and other rural capital to their QoL in Hokuto City. Such natural capital includes farmland, symbolic natural sites, mountain peak view, lower temperature, and

tranquility. Other rural capital are built capital (highways, railway stations, and shops and restaurants) and financial capital (employment). Many of these are related to the reasons that migrants chose their present home location in Hokuto City, indicating their increased QoL by migration. Particularly, one-way migrants are selective in choosing their home locations, which were predominantly on higher up mountain slopes with lower temperatures, higher forest cover, near natural parks, and symbolic natural sites, and yet with easier access to railway stations and employment. These results provide a valuable knowledge base for rural spatial planning for increased QoL and number of migrants that considers ecological–social feedbacks, and hence supports a shift to a deurbanization pathway which is attracting even more attention in the post-COVID-19 world. In future research, a more comprehensive and optimized set of geospatial indicators could also be sought for a more balanced representation of key natural, built, social, human, financial, and cultural capital. Further, studies on the ecological consequences of urban-to-rural migration are needed for a more comprehensive understanding of the feedback loop between nature and human behavior in the deurbanization context.

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Declarations

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