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Title

Simulation of Natural Capital and Ecosystem Services in a Watershed in Northern Japan Focusing on the Future Underuse of Nature
-By Linking Forest Landscape Model and Social Scenarios-

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1 **Abstract**

2 A quantitative scenario approach to compare the future state of natural capital

3 and ecosystem services (ESs) plays a key role in facilitating decision making for

4 the sustainable management of landscapes. In Japan, the shrinking and aging

5 population will likely lead to a situation of underuse of natural resources, resulting

6 in rewilding of terrestrial ecosystems. This study conducted a quantitative

7 scenario analysis of natural capital and ESs by linking model and social scenarios

8 on a local scale. The case study area was the Bekanbeushi River Watershed in

9 northern Japan. LANDIS-II model (a forest landscape model) was used to

10 simulate the vegetation dynamics in species composition, age structure and

11 biomass considering impacts of forest and pasture land management. Four

12 "population distribution" and "capital preference" scenarios were translated into

13 forest and pasture land management. The population distribution and capital

14 preference assumptions resulted in different consequences for natural capital and

15 ESs. The population distribution affected the spatial allocation of abandoned

16 pasture land and level of isolation of managed pasture land. The capital

17 preference assumptions largely affected the consequences for ESs. Finally, these

18 simulation results demonstrated the capacity to feed quantitative information to

19 the narrative scenarios. Our process-based approach provides insight into the

20 relationships among social drivers, ecological processes and the consequences

21 that will affect natural capital and ESs, which can contribute to decision making

22 and sustainability design of regions, which may face issues associated with

23 underuse in the future.

24

27

Introduction

Natural capital is defined as ecosystems that provide ecosystem services, analogizing the general definition of capital as stock that yields a flow of services over time (Costanza and Daly 1992; Costanza et al. 2017). Therefore to sustain ecosystem services, it is necessary to carefully consider the maintenance and management of natural capital. Quantitative scenario analysis facilitates the comparison of diverged plausible futures, and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) suggested that scenarios and models of indirect drivers, direct drivers, nature, nature's benefits to people, and good quality of life need to be better linked to improve the understanding and explanation of the important relationships and feedback between these components of coupled social–ecological systems (IPBES 2016).

Underuse of natural resources is one of the critical social drivers which alters natural conditions worldwide. Some regions, such as Europe, East-Asia, North America, and Oceania, are facing a situation of underuse due to the shrinking and aging population of farmers and foresters, as well as the changes in policies and economic conditions (Mauerhofer et al. 2018). The underuse problems were mainly researched in Europe and East-Asia in terms of biodiversity conservation. It was suggested that the effectiveness of conservation strategies is generally unclear, and shedding light on the mechanisms and consequences of underuse is important.

Japan is a representative country of an aging and shrinking population (Cabinet Office Japan 2016), and this situation results in the underuse of natural resources, especially in rural regions (Japan Biodiversity Outlook Science Committee 2015). The underuse of natural resources is one of the major driving forces likely to change Japanese terrestrial ecosystems and cause farmland abandonment and vegetation transition which will affect the biodiversity and ESs in the future (Japan Biodiversity Outlook Science Committee 2015). Although scenario analyses have been conducted in Japan to assess the impact of underuse of natural resources, these studies were somewhat limited. The Japan *Satoyama Satoumi* Assessment (JSSA) conducted a scenario analysis in *Satoyama* and *Satoumi* landscapes, which are traditional socio-ecological production landscapes

60 and seascapes in Japan (JSSA 2010). In the JSSA report, a variety of assessment

61 sites were selected and grouped into five major clusters across Japan. Four future

62 scenarios were then generated by following two scenario axes according to the

63 framework of the Millennium Ecosystem Assessment (MA 2005): Local or Global,

64 and Nature-Oriented or Technology-Oriented. However, the output of the JSSA

65 report was limited to the qualitative scenario assessment of ESs based on

66 subjective expert judgment.

67   To overcome this limitation, the Predicting and Assessing Natural Capital

68 and Ecosystem Services (PANCES) project was launched to develop the

69 integrated model of social–ecological systems which consist of population, land

70 use and natural capital sub-models (PANCES 2016; Takeuchi et al. 2017). Future

71 scenarios provided by the PANCES project adequately represent the way of

72 utilizing natural capital under the future shrinking society in Japan (Saito et al.

73 2018). This PANCES project also provides social drivers such as population

74 distribution and capital preference under each plausible scenarios, which will

75 contribute to predicting impacts of underuse of natural resources and making

76 domestic and international biodiversity assessment frameworks.

77   The consideration of processes and feedbacks among social drivers and

78 ecological systems is essential for integrated analysis of social-ecological systems

79 (Carpenter et al. 2009). The demographic conditions have been used to translate

80 scenarios into land use and land cover change using land change models to

81 evaluate ecosystem services (e.g., Estoque and Murayama 2012; Syoyama and

82 Yamagata 2014). For example, Shoyama and Yamagata (2014) quantitatively

83 projected land-use transitions for each scenario using the empirical model Dyna-

84 CLUE (Verburg and Overmars 2009) and evaluated the future ESs based on the

85 InVEST model (Tallis et al. 2011) in the Kushiro watershed in Japan. In the

86 scenario where farmland abandonment progresses due to underuse, the

87 supporting and provisioning services are projected to decline as local

88 communities disappear. However, the Dyna-CLUE model projects future changes

89 based on empirical trends. Also, the InVEST model converts land use (ha) to ESs

90 multiplying predetermined conversion factor (e.g., Mg-C ha^{-1}). These models did

91 not take ecological dynamics and status into consideration, while the ecological

92   dynamics such as farmland abandonment and following forest succession will
93   affect the property of natural capital and ESs (Japan Biodiversity Outlook Science
94   Committee 2015). Thus, scenario analysis of natural capital and ESs in Japan
95   need to be quantitatively conducted, and ecological processes of natural change
96   and its effect on natural capital and ESs must be taken into consideration in terms
97   of planning effective human intervention as the next logical step in this field of
98   study.

99   Forest Landscape Models (FLMs) have advantages in simulating
100 landscape-scale processes, including forest succession, seed dispersal, natural
101 disturbances (e.g., fire, wind, insect, and browsing), and forest management
102 activities (Xi et al. 2009; Shifley et al. 2017). Among the FLMs, LANDIS-II can
103 simulate the cyclic accumulation of biomass, carbon, and nitrogen, and it has
104 been widely used (Dai et al. 2015) and embedded in a climate change assessment
105 model (MOSAICC model) (FAO 2015). FLMs are widely used for scenario analysis
106 of forest management at a local scale, while the tighter coupling of socio-
107 economic drivers is still challenging (Shifley et al. 2017). Forest succession under
108 each narrative scenario simulated using the FLMs, and outputs were evaluated in
109 terms of biodiversity and ecosystem services, such as the resilience of biomass
110 and species composition and multiple ESs (Swearingen et al. 2015; Price et al.
111 2016; Thompson et al. 2016a; Lucash et al. 2017), whereas management rules
112 under scenarios was determined by expert judgment.

113   The purpose of our study is to conduct a quantitative scenario analysis
114 of natural capital and ESs by linking LANDIS-II model and the PANCES scenarios.
115 The study offers some important insights into 1) the effects of ecological
116 dynamics on natural capital and ESs in the context of future underuse trends in
117 Japan, and 2) the coupling of FLMs and social drivers under each scenario at a
118 local scale. Therefore, the specific objectives include: 1) the translation of
119 narrative scenarios into practical management options that can be input to the
120 model directly, 2) the simulation of vegetation succession under different
121 scenarios, and 3) the visualization of consequences for natural capital and ESs,
122 with a discussion of its impacts on local communities. The effectiveness of this
123 study is also discussed by comparing the results with previous scenario analyses

124   studies.

125

Materials and methods

Description of LANDIS-II model

The LANdscape DIsturbance and Succession model (LANDIS-II), which is one of the prominent FLMs, was designed to simulate the biomass and material cycle for each species cohort and the various disturbance events on grid cells at large landscape scales (Scheller et al. 2007). LANDIS-II represents landscapes as grid cells, and each cell consists of the cohorts defined by tree species name and age information. The surrounding species composition of forests and environmental factors affect vegetation transition pathways. Therefore, forest landscape dynamics such as seed dispersal is modeled explicitly from a spatial perspective.

LANDIS-II NECN succession v4.2 (Scheller et al. 2011) was selected from the model's various functions in this study. The NECN succession is suitable to evaluate the impact of climate change and carbon and nitrogen cycling for future assessment efforts. In NECN succession, biomass growth and seedling establishment are designated as functions of environmental conditions. Biomass growth is calculated by the difference between monthly net primary production (NPP) and monthly mortality. NPP is calculated by multiplying the monthly maximum aboveground NPP (maxANPP) by environmental limiting factors corresponding to the monthly mean of daily maximum and minimum temperatures, nitrogen availability, soil moisture, shading, and density effect. The monthly mortality is a function of the aboveground biomass and its age. In relation to seed dispersal and seedling establishment, the NECN succession uses a simplified algorithm. First, the NECN succession calculates the arrival probability of seeds from other cells. In the process, the effective and maximum seed dispersal distance for each species decides a probability distribution for seed dispersal. The establishment probability is then calculated stochastically, depending on the shade tolerance by tree type, temperature and soil-water conditions. The species-specific parameters for the NECN succession can be found in S1, and the calibration and validation processes are shown in S2 of the electronic supplementary materials.

Site description

ESs evaluation worldwide has been performed at various spatial scales depending on the research question (Englund et al. 2017), and finer scale analyses is essential for understanding both win-win and trade off relationship of biodiversity and ESs and for targeting specific conservation actions (Naidoo et al. 2008). The case study area was the Bekanbeushi River Watershed (between 42°59'48" N and 43°21'15" N in latitude and 144°36'17" E and 145°00'26" E in longitude) in the eastern Hokkaido prefecture (Figure 1). In this watershed, the population of workers in the primary industry have continuously decreased since 1960 (Akkeshi town 2017; Shibecha town 2017). The major industries include fishery, forestry, and pasture grass production for dairy farming (Akkeshi town 2017). Population is projected to decline to 52% of 2015 levels by 2045 (NIPSSR 2018). Therefore, the abandonment of forestry and agriculture due to the shortage of workers and its impact on the local ecosystems are key concerns in the region and considered to be suitable for a case study of underuse problems.

The area of this watershed is approximately 700 km^2 and consists of various ecosystems such as forests (c.a. 70%), pasture land (c.a. 20%), and wetlands (c.a. 4%) registered in the Ramsar Convention in 1993. In national forests in the northern part of the watershed, the main vegetation consists of Japanese larch (*Larix kaempferi* (Lamb.) Carrière) plantations. The species composition in prefectural forests in the southern area is Todo fir (*Abies sachalinensis* (F.Schmidt) Mast.) plantations and mixed forests of Todo fir–Japanese oak (*Quercus crispula* Blume).

Future scenarios

Social scenarios developed on a national scale by Saito et al. (2018) were used as the base context. This national scenario consists of two bidirectional aspects specifying four different future visions (Figure 2). Four scenarios are represented by the following two scenario axes in the future: "population distribution" and "capital preference." The former assumption decides the two types of population distribution: dispersed population (Dsp) and urban compactification (Cmp). The Dsp scenario assumed that rural communities will be maintained by a

190   decentralized approach, while in the Cmp scenario, people will move from rural

191   to urban areas, which will result in the accelerated disappearance of rural

192   communities. The latter assumption characterizes people's capital preferences.

193   The natural capital basis (Ntr) utilizes more local natural capital (e.g., domestic

194   timber use), and the produced capital basis (Prd) utilizes more goods produced

195   and imported from elsewhere, thereby relying on foreign natural capital.

196   In this study, scenarios in the watershed were set by localizing the

197   national scenarios in terms of the social context of the region. First, a business

198   as usual (BaU) scenario was defined by assuming that past trends of forestry and

199   agriculture will continue in the future. Four future scenarios were set by referring

200   the BaU scenario as follows. In relation to the assumption of capital preference,

201   the primary industries were assumed to actively manage the local forest and

202   farmland in the Ntr scenarios, while the local natural capital was assumed to be

203   gradually abandoned in the Prd scenarios. In terms of population distribution, it

204   was assumed that people will remain in the watershed and continue to manage

205   local natural capitals in the Dsp scenarios, whereas the management of remote

206   farmlands far from residential grid cells will gradually become more challenging

207   to manage because of population out-migration in the Cmp scenarios.

208

209   **Forest management setting**

210   Biomass Harvest Extension v3.2 (Scheller and Domingo 2018) of LANDIS-II

211   model was used to simulate forest management activities under each scenario.

212   The Biomass Harvest Extension enables the setting of the target species, the

213   proportion of the biomass to be removed, and the proportion of target cells which

214   are managed each year (management intensity). In the watershed, Todo fir and

215   Japanese larch is the target species of forestry (Hokkaido 2017a), thus, clear-

216   cutting and thinning rules for the two species were designed based on a regional

217   forest management plan (Hokkaido 2017a). These forestry practices were applied

218   to the stands (forest management unit) containing mature Todo fir and Japanese

219   larch in descending order of mean cohort age until the total harvested area

220   reaches the annual management intensity.

221   The management intensity in 2050 was set by the capital preference

222 assumption (Table 1). The initial management intensities of "clear cut and
223 plantation," "clear cut and natural regeneration," and "thinning" in 2015 were
224 determined so that the mean harvest areas during 35-year simulation in the BaU
225 scenario become as same as the actual value by regional forestry statistics. (row
226 one on Table 1) (Hokkaido 2017b); the rotation period of clear cutting ranged
227 from 133 years (0.075% per year) to 400 years (0.025% per year), and that of
228 thinning was approximately 75 years (1.3% per year). These rotation periods
229 were much longer than the standard rotation periods in the region (Hokkaido
230 2017a). In the BaU scenario, forestry practices were assumed to continue the
231 present management intensities from 2016 to 2050 (row two on Table 1). In the
232 Ntr scenarios, people utilize local timber products and actively manage the forest
233 in the watershed, so the management intensities of Todo fir and Japanese larch
234 clear cutting were assumed to linearly increase to 1.7 and 2.0% in 2050,
235 respectively (row three on Table 1). These management intensities were decided
236 by the standard rotation periods of Todo fir (60 years) and Japanese larch (50
237 years). According to the regional standard, the management intensity of Todo fir
238 and Japanese larch thinning was set to 4 times per 60 years (15% per year) and
239 4 times per 50 years (12.5% per year), respectively. The proportion of the
240 removed biomass by thinning was set as 26.5% according to the regional forest
241 management plan (Hokkaido 2017a) and 100% by clear-cutting. In the Prd
242 scenarios, forestry was assumed to be abandoned, and therefore, management
243 intensity of clear cutting and thinning was set to decrease linearly to 0% by 2050
244 (row four on Table 1). The manageability of forestry practice was assumed to be
245 the same, while the manageability of pasture land was considered somewhat
246 different, as described in the next section. This is because the frequency of
247 forestry practices is lower than pasture land management practices, in general.
248

249 **Pasture land management setting**
250 Pasture land management and abandonment was represented by LANDIS-II
251 Biomass Harvest Extension v3.2 (Scheller and Domingo 2018) according to
252 Middendorp et al. (2016). In this region, pasture management is conducted from
253 April to October, including approximately 2 harvesting events (758 kg 10a^{-1})

254 (Nemuro Agriculture Improvement Promotion Center 2016) and 3 fertilizing
255 events (10 gN $m^{-2}y^{-1}$ nitrogen) (Hokkaido 2015). According to the agricultural
256 census, the farmland abandonment ratio was 0.89% in 2005 and 1.37% in 2015,
257 which is an annual increase of 0.048 % yr^{-1} (2005 to 2016 in Figure 3) (Ministry
258 of Agriculture, Forestry and Fisheries 2018). The Biomass Harvest Extension
259 assumed to remove both pasture grass and other species established in each cell
260 every year until the pasture land in the cell became abandoned.

261   In the BaU scenario, the abandonment ratio was set to increase 0.048 %
262 annually until 2050 (solid line in Fig. 3). In the Ntr scenarios, abandoned pasture
263 land in 2015 was assumed to be gradually re-cultivated, and the abandoned
264 farmland ratio became 0% in 2050 (dashed line in Fig. 3). On the other hand,
265 the dependence on imported foods was assumed higher in the Prd scenarios.
266 Therefore, the annual increment in the farmland abandonment rate was set to
267 1.35%, and the abandonment rate was projected to be 48.8% in 2050 (dotted
268 line in Fig. 3). This increment rate is equal to the highest 95% of the increase
269 rate of farmland abandonment ratio among all municipalities in Japan from 2005
270 to 2015 (S3 of the electric supplemental materials) (Ministry of Agriculture,
271 Forestry and Fisheries 2018).

272   Population distribution was assumed to affect the manageability of
273 pasture land, and pasture land that has a lower manageability value assumed to
274 be abandoned earlier. The gridded population distribution under each scenario
275 was derived from the PANCES project at 1 km resolution (Figure 4) (Matsui et al.
276 2018). In the PANCES project, BaU follows the population distribution in 2050
277 estimated by the National Spatial Planning and Regional Policy Bureau (Ministry
278 of land, Infrastructure, Transport and Tourism 2018). The spatial allocation of
279 population reflects the population distribution rule for each scenario. In the BaU
280 scenario, population in the watershed decreased from 8,604 to 4,148, and the
281 population was concentrated in the center of the town of Akkeshi in the coastal
282 area. In the urban compactification (Cmp) scenarios, it was assumed that people
283 moved to neighboring Kushiro and Naka-Shibetsu, and the population in the
284 watershed eventually decreased to zero. In the dispersed population (Dsp)
285 scenarios, although it was assumed that some people would remain in the

286 watershed in 2050, the population decreased from 8,604 to 4,940.

287   Therefore, manageability of each pasture land was calculated from

288 Equation (1).

289 $$Y_i = \frac{pop_i}{distToResi_i} \times \frac{1}{distToRoad_i} \times \frac{1}{meaSlope_i} \times \frac{1}{meaElev_i},\qquad(1)$$

290 where Y_i is the manageability of cell i, and pop_i and $distToResi_i$ denote the

291 population in the nearest residential grid cell and the distance to the nearest

292 residential grid cell from cell i, respectively. $distToRoad_i$ is the distance to the

293 nearest road from cell i (Conservation GIS-consortium Japan 2017), and

294 $meaSlope_i$ and $meaElev_i$ represent the mean slope and the elevation of cell i

295 (National Land Numerical Information download service 2017). These variables

296 were standardized from 1 to 2.

297

298 **Model simulation**

299   **Landscape initialization**

300 The total simulated area within the watershed was 50,415 ha. LANDIS-II

301 represents the landscape as grid cells, and the cell size was set at 100 m referring

302 the mean size of each forest management unit in this area. Wetland areas were

303 excluded from the simulation because the scope of this study was to assess the

304 impact of underuse of manageable ecosystems, which does not apply to wetlands.

305   LANDIS-II estimates initial aboveground biomass of each cohort through

306 spin up simulation based on the species name and its age information in each

307 cell (Scheller et al. 2018). In this study, the distributions of tree species were

308 obtained from a vegetation map (Biodiversity Center of Japan 2017). In the

309 vegetation map, the vegetation distribution at the community level was recorded,

310 therefore, we decided the representative species for each community from the

311 community's name (S4 of the electronic supplemental materials). The age

312 information was added by the forest register of national, prefectural, and private

313 forests (Ministry of Agriculture, Forestry and Fisheries 2017a; Hokkaido 2017c).

314 To reduce the complexity of the simulation, the most dominant communities in

315 the watershed were selected, which represent 94% of the total coverage (S4),

316 and as the result, 10 species were taken into account in this study (Table 2).

317

Environmental variable setting

Environmental conditions were set by ecoregion in LANDIS-II. In the NECN succession, users can input the soil and climatic conditions. The initial soil conditions were individually set for the pasture land and the forest ecoregion. The allocation parameters of soil organic matter (SOM) pools were set by the parameterization workbook of the CENTURY soil organic matter model (CENTURY4 2000). The decay rate of each SOM pool was obtained from the user guide of the NECN succession (Scheller et al. 2018). Soil-water condition was calculated to estimate the plant available water using a simple bucket model with the soil's physical parameters, such as soil depth and the percent of clay and sand, which were determined from available literature (Hokkaido National Agricultural Experiment Station 1983).

With respect to the climatic setting, the ecological processes, such as the growth of aboveground biomass and the decomposition of dead wood and soil organic matters, respond to climatic conditions, thus, monthly maximum and minimum temperatures and monthly precipitation were required. In Japan, climate change is regarded as the "fourth crisis" of biodiversity (Japan Biodiversity Outlook Science Committee 2015). Recent studies suggest that the potential habitat of some broad-leaved tree species will expand to cool temperature zones (Nakao et al. 2014), and the vegetation succession process will also be affected by climate change (Laflower et al. 2016). These climate change effects cannot be ignored in the mid- and long-term future forecasts of tens to hundreds of years targeted by the scenario approach. In this study, climate change is assumed to be the baseline trend, and climatic conditions under the IPCC RCP8.5 scenario calculated by the MRI-CGCM3 were thus selected from the CMIP-5 project database (ESGF-CoG 2017). The grid size was approximately 1 degree in latitude and longitude, and the grid covers the entire study area. Therefore, the distribution of climatic conditions was assumed to be uniform. To correct the bias between climatic values from MRI-CGCM3 and observation, monthly temperature and precipitation offsets were determined by comparing data from the model and the Ota Meteorological Observatory, which is located

349 within the watershed (<mark>Japan Meteorological Agency 2018</mark>), and the offset values
350 were applied to future climate data. Annual rainfall is estimated to increase by
351 115 mm, and the annual means of monthly maximum and minimum
352 temperatures to increase by 1.5 °C and 2.1 °C in the 2040s, respectively (<mark>S5 of</mark>
353 <mark>the electronic supplementary materials</mark>).
354

355 **Simulation conditions**
356 By combining the assumptions of capital preference (Ntr and Prd) and population
357 distribution (Cmp and Dsp), four future scenarios (PrdCmp, PrdDsp, NtrCmp, and
358 NtrDsp) and a BaU scenario were simulated under the RCP8.5 climate scenario
359 obtained from the MRI-CGCM3. The duration was 35 years, from 2016 to 2050.
360 The time step for vegetation succession was set at 1 year, and the biomass
361 growth and cohort mortality were calculated in monthly time steps.
362

363 **Evaluation of natural capitals and ESs**
364 Natural capital was evaluated by considering the composition and diversity of the
365 land cover and aboveground biomass at the watershed scale. In this study, land
366 cover was defined as a tree species with the largest biomass in each cell. It should
367 be noted that, if the cell contains multiple species, non-dominant species were
368 ignored for land cover types.
369 The diversity of land cover and biomass was calculated using Simpson's
370 diversity index (SD), as expressed by <mark>Equation (2)</mark>,

371 $$SD_t = 1 - \sum_{i=1}^{S}\left(\frac{N_{t,i}}{Ntotal_t}\right)^2, \qquad (2)$$

372 where SD_t is Simpson's diversity index at the watershed scale for year t. For land
373 cover, S is the total number of land cover types, $N_{t,i}$ is the number of cells for
374 land cover i in year t, and $Ntotal_t$ is the total number of active cells. For
375 aboveground biomass, S is the total number of tree species, $N_{t,i}$ is the biomass
376 of species i in year t, and $Ntotal_t$ is the total biomass at the watershed scale.
377 To analyze the impact of pasture land abandonment on landscape
378 patterns, the perimeter and area of each pasture land patch were calculated using
379 FRAGSTATS software (version 4.2).

380   Regarding ESs, the timber and pasture grass provisioning and carbon
381   sequestration services were evaluated by the harvested timber and pasture and
382   net ecosystem exchange (NEE), respectively. In this study, the carbon
383   sequestration service is evaluated by the net ecosystem exchange and is
384   calculated using Equation (3),

385    $ES_{carbon\ sequestration} = \sum_{t=2016}^{2050} \sum_{i=1}^{L} \sum_{j=1}^{N} (-NEE_{t,i,j} \times 10^4),$ (3)

386   where $ES_{carbon\ sequestration}$ is the cumulative amount of sequestrated carbon at the
387   watershed scale, and $NEE_{t,i,j}$ (gC m^{-2}) is the simulated annual total net ecosystem
388   exchange (NEE) on cell j of land cover type i in year t. NEE represents the net
389   carbon balance of plant and soil layer and is calculated by the heterotrophic
390   respiration minus NPP. L denotes the total number of land cover type and N is the
391   total number of cells in land cover type i in year t.

392

Results

Natural capital: Changes in land cover

The assumptions related to capital preference and population distribution affected the total area and the distribution of abandoned pasture land (Figure 5). In terms of capital preference, pasture land decreased by 45% in the Prd scenarios and decreased by 3% in the BaU scenario over the simulation periods (S6 in the Electronic Supplemental Materials). After the pasture land was abandoned, mainly Japanese white birch established and grew because Japanese white birch is a pioneer species in the region having the lowest shade tolerance and the longest seed dispersal distance among the 10 species considered (S1(a)).

In the two Prd scenarios, the population distribution affected the spatial arrangement of abandoned pasture land because the accessibility components associated with each pasture land are different, as indicated in Eq. 1. In the PrdCmp scenario, people migrated to the cities outside the watershed such as Kushiro (47 km west from the watershed) and Naka-Shibetsu (77 km north from the watershed) by 2050 (Fig. 4(c)). Table 3 shows the mean score of the components in Eq. 1 among the abandoned pasture land in 2050 when the ratio of abandonment reached 48.8% for Prd scenarios. In both Prd scenarios, elevation (meaElev$_i^{-1}$) had a significant impact. In the PrdCmp scenario, the distance to the nearest residential grid cell affected the distribution of the abandoned pasture land. Therefore, the southeastern and northwestern pasture lands far from these cities were largely abandoned (Fig. 4(c) and Fig. 5). In the PrdDsp scenario, people remained in the watershed in 2050 (Fig. 4(d)), and thus, geographical conditions such as elevation and slope were the major driving forces affecting pasture land abandonment (Table 3).

The assumptions related to capital preference and population distribution also affected the patch metrics of pasture land (S7 of the Electronic Supplemental Materials). The number of patches of pasture land increased in all scenarios, while the mean area and the mean perimeter decreased in all scenarios. In particular, the PrdCmp and PrdDsp scenarios showed significant changes, and the number of patches increased from 141 to 206 and 193, mean area decreased from 108

ha to 41 and 43 ha, and mean perimeter decreased from 10.8 km to 4.3 and 4.7 km, respectively.

In the two Ntr scenarios, all pasture lands were conserved, and some parts of the Japanese larch forest in the middle north were shifted to Japanese white birch through natural regeneration after clear-cutting (Fig. 5).

In all scenarios, the abandoned pasture lands (pasture grass in 2016) were mainly dominated by Japanese white birch by 2050 (S6). Todo fir and Japanese larch shifted to Japanese white birch and Japanese alder after natural regeneration. The Japanese white birch dominated in the mixed forest of Japanese white birch and Japanese oak and was distributed mainly in the northern region (Fig. 5) in 2016. After 35 years, the mixed forest was dominated by Japanese oak because of the difference in the longevity of the two species, where the longevity of Japanese white birch and the longevity of Japanese oak were 100 and 400 years, respectively. In the mixed community of Japanese oak and Todo fir in the southeast of the study area, the dominant species shifted from Japanese oak to Todo fir because the maximum biomass of Todo fir is higher than that of Japanese oak (S2).

These vegetation transitions altered the composition of land cover (Figure 6). Capital preference affected the total amount of the abandoned pasture land and the clear-cutting area. In the Prd scenarios, pasture land decreased with progress in pasture land abandonment, and Japanese white birch increased in these cells compared to the BaU scenario (S6). In the Ntr scenarios, Japanese white birch established and grew following natural regeneration after clear-cutting of the Japanese larch (S6). Consequently, Japanese white birch increased in both scenarios compared with the BaU scenario. The landscape diversity value at the watershed scale was 0.83 in the Prd scenarios and was slightly higher than that of the BaU and Ntr scenarios in the year 2050 (0.80).

Natural capitals: Changes in biomass

The composition and total amount of the AGB at the watershed scale were substantially affected by capital preference (Figure 7). In the BaU scenario, the AGB of Japanese white birch decreased because of age-related mortality. The

456 AGB of Japanese larch increased by 405 Gg-biomass due to the increase in
457 mature cohorts which were not clear cut. In the PrdCmp and PrdDsp scenarios,
458 the total amount of AGB was 964 and 931 Gg-biomass, respectively, which were
459 both higher than BaU. Japanese white birch forest expanded in the abandoned
460 pasture land, and the AGB of the species in the PrdCmp and PrdDsp scenarios
461 increased by 434 and 421 Gg-biomass compared with the BaU scenario, even
462 though that of Japanese white birch decreased in forest cells because of age-
463 related mortality. In the forest ecosystems in the PrdCmp and PrdDsp scenarios,
464 the AGBs of Japanese larch slightly increased by 38 and 45 Gg-biomass, and that
465 of Todo fir increased by 40 and 62 Gg-biomass over that in the BaU scenario,
466 respectively. In the NtrCmp and NtrDsp scenarios, the total AGB was 1499 and
467 1511 Gg-biomass below the BaU scenario. This is because the AGB of Japanese
468 larch decreased 887 and 888 Gg-biomass and that of Todo fir decreased 311 and
469 305 Gg-biomass than the BaU scenario, respectively, due to the promotion of
470 timber harvesting activities. In both the Ntr and Prd scenarios, the species
471 diversity based on the AGB of each species at the watershed scale was 0.80
472 among the Prd and Ntr scenarios and only slightly higher than that of the BaU
473 scenario (0.79).

474

475 **Provisioning services: Timber and pasture provisioning**

476 The capital preference affected both timber and pasture yields (Figure 8). In the
477 Ntr scenarios, the total timber yield was approximately 2.8 times higher than the
478 yield in the BaU scenario because of active forestry. Japanese larch and Todo fir
479 were harvested at levels that were 7.3 and 2.2 times higher than harvesting
480 levels in the BaU scenario, respectively. The total amount of pasture grass
481 production in the BaU and Ntr scenarios were virtually identical, but was 20%
482 less in the Prd scenarios.

483

484 **Regulating service: Carbon sequestration**

485 The carbon sequestration service of the Ntr and Prd scenarios was 1.2 and 1.1
486 times higher than that in the BaU scenario, respectively (Table 4), while the major
487 carbon sinks differ among the scenarios. The land cover, which was dominated

488 by Japanese larch, Japanese white birch, and pasture grass, was net carbon sink
489 in all scenarios. In the Ntr scenarios, Japanese larch sequestrated 2.3 times more
490 carbon than the amount sequestered in the BaU scenario because the mean age
491 of the species became younger over time by activate forestry practice. By
492 contrast, the amount of sequestered carbon by the Todo fir decreased compared
493 with the BaU scenario due to the lower growth rate as compared to the Japanese
494 larch (S2) and the decrease in coverage area (S6). Japanese white birch forest
495 was established after the "clear cutting and natural regeneration" resulting in the
496 increase of the service. In the Prd scenarios, Todo fir and Japanese larch became
497 mature and the carbon sequestration service decreased because of the low
498 management intensities. The major sink of the Prd scenarios was Japanese white
499 birch which established and grew following pasture land abandonment, while the
500 carbon sequestration by pasture grass decreased.
501
502 **Comprehensive comparison among future scenarios**
503 The assumption of population distribution and capital preference led the different
504 consequences among the scenarios. The population distribution affected both the
505 spatial allocation of abandoned pasture land (two Prd scenarios in Fig. 5) and the
506 patch metrics of managed pasture land (S7) in the PrdCmp and PrdDsp scenarios.
507 The patch number of managed pasture land in the PrdCmp scenario was larger
508 and the perimeter and area were smaller than those in the PrdDsp scenario. This
509 suggested that the managed pasture land was more isolated in the PrdCmp
510 scenario.
511   The assumption of capital preference largely affected the consequences
512 for ESs in the watershed. The Ntr scenarios had an advantage in terms of species
513 diversity based on the AGB, the timber and pasture yields (Fig. 8), and total
514 carbon sequestration (Table 4), while active management negatively impacted
515 the changes in the amount of biomass (Fig. 7). In the Prd scenarios, changes in
516 the amount of biomass (Fig. 7) and landscape diversity were maximized. The
517 BaU scenario ranked between the Prd scenarios and the Ntr scenarios from the
518 perspective of biomass change and timber and pasture yields, while landscape
519 and species diversity was the lowest among the scenarios.

520   The effect of forestry practices on carbon sequestration differed among
521   species due to the difference in growth rates. Both Japanese larch and Todo fir,
522   which are the target species of forestry in this region, experienced higher rates
523   of clear cutting and thinning in the Ntr scenarios. As the result, Japanese larch
524   increased both the timber provisioning and carbon sequestration services, while
525   the carbon sequestration of Todo fir decreased compared with the BaU scenario.
526   However, Todo fir has a potential to increase carbon sequestration in the future
527   as long as it is managed continuously. These results suggested that the model
528   simulation enables us to understand complex effects of landscape management
529   practices on carbon sequestration.
530

Discussion

Scenario improvement by feeding back simulation results

The results of this study can feed quantitative information to the narrative scenarios provided by the PANCES project (Saito et al. 2018), which were localized by the future vision for the town of Akkeshi (Akkeshi town 2016) (Table 5). The row titles in Table 5 were consistent with the main framework of the PANCES scenario (Saito et al. 2018), and the column titles represent the scenario names.

First, "Industrial structure and economy" complemented by the concrete management intensity and the expected timber and pasture grass yields. In produced-capital-based societies (Prd), the spatial distribution of abandoned pasture land was characterized by the manageability under each scenario (PrdDsp or PrdCmp) using Eq. 1.

The "Infrastructure and policy" was localized, referring to population distribution in 2050 (Matsui et al. 2018) and the local future vision of Akkeshi town (Akkeshi town 2016). In natural-capital-based societies (Ntr), people are assumed to utilize the local natural capital and ESs. The difference between NtrCmp and NtrDsp is where the forestry and agricultural workers live and engage in the utilization of them. To vitalize agriculture and forestry, collaboration and job creation will be promoted. In contrast to this, under the Prd scenarios, landscape managements will be gradually abandoned.

Finally, local community conditions and contact with nature in "Culture and Value" were discussed. In the Dsp scenarios, local communities were vitalized through job creation, while people moved out of the watershed, leaving no residents by the year 2050 in the Cmp scenarios. In the Ntr scenarios, people was assumed to conserve the local ecosystems, and local residents continued traditional contact with nature and wildlife in the NtrCmp scenario, while people outside the watershed managed them in the NtrDsp scenario. In low management intensity societies (Prd), the area of forest increased because of pasture land abandonment, and pasture lands become isolated, especially in the PrdCmp scenario. This can cause a habitat change for wildlife such as the Hokkaido sika deer and Brown bear, and inefficiency of pasture land management. From a perspective of living with nature, a potential for conflict between human

564 and wildlife still remains in two Prd scenarios because people continue to live in
565 the watershed in the PrdDsp scenario and pasture workers from outside
566 watershed visit to manage the pasture land in the PrdCmp scenario.
567

Limitation and Challenge

569 This study defined future management intensity of forestry and pasture
570 considering assumptions of population distribution and capital preference
571 provided by the PANCES scenarios, while previous studies visualized the
572 consequences of each scenario by setting plausible management case by expert
573 judge (Swearingen et al. 2015; Price et al. 2016; Thompson et al. 2016a; Lucash
574 et al. 2017). This approach successfully demonstrated the effect of those
575 assumptions on future state of natural capital and ESs and will make an important
576 contribution to the development of an integrated model of socio-ecological
577 systems.

578 Our study is capable of covering the provisioning services of materials
579 (timber and pasture grass) and climate regulation service. The results of timber
580 and pasture grass yield can be used to evaluate the energy supply potential (De
581 Jong et al. 2007; Oba et al. 2016) and food provisioning by integrating our results
582 and other models (FAO 2015). The JSSA report evaluated four scenarios using
583 13 types of ESs indices (six provisioning services, three regulating services, and
584 four cultural services) even though they were qualitative, so still we have many
585 challenges in the quantitative evaluation of the other ESs.

586 The previous spatially explicit scenario analysis at the local scale
587 (Shoyama and Yamagata 2014) projected future land use change using machine
588 learning approaches and past land use data. This approach projects the future
589 land use change by extrapolation with the past trends assuming stationarity
590 (Brown et al. 2013; Shoyama et al. in press). However, this approach can bring
591 biased results if the past trends will not continue in the future due to
592 inexperienced social transition such as rapid population decline and aging. Our
593 process-based approach can simulate future land cover in underuse situation by
594 calibrating management intensities, which enabled us to better understand the
595 relationships between the changes in ecological processes and the consequences

596   of natural capital and ESs; farmland abandonment and changes in landscape
597   metrics and climate regulation service, and forestry practices and timber
598   provisioning services and carbon sequestration service. As a future direction, the
599   land use change projection can be used for input data of ecological process
600   models. Recently, challenges coupling with land change modeling and ecological
601   process models are emerging (Thompson et al. 2016b; Shoyama et al. 2017).
602   However, important limitations and challenges still remain as below.
603

604   **Scenario translation**
605   In this study, the assumption of population distribution and capital preference
606   were considered to be independent of one another. Further studies are needed to
607   introduce the interactions and systematic changes of those indirect drivers such
608   as capital, demographics, and infrastructure to design much more plausible
609   management strategies for forestry and farmland abandonment in different
610   scenarios. For example, the usage of the system dynamics model in the scenario
611   translation process (Mallampalli et al. 2016) can help explain the interaction
612   between social-economic drivers, indirect drivers such as the demand, and direct
613   drivers such as management intensity.

614   To evaluate impacts on vegetation succession under social and climate
615   change, a longer-term simulation is expected. Administrative management plans
616   are set from several years to several decades, while ecological changes in the
617   forest ecosystems are extended for much longer durations. This gap in the time
618   horizon may cause the over or under estimation of some ESs. For example, in
619   this study, the simulation period was 35 years, from 2016 to 2050, referring to
620   relevant administrative plans, and the result showed the early successional stage
621   with the expansion of pioneer species such as Japanese white birch and Japanese
622   larch.
623

624   **Improvement of model reliability**
625   LANDIS-II NECN succession was localized in Japanese ecosystems by collecting
626   the species-specific parameters and calibrating empirical data, as shown in S1
627   and S2. To validate the output of LANDIS-II, the forest register in the region was
628   used. However, the forest register mainly recorded commercial species, such as

629 Japanese larch and Todo fir, and the data for natural forests was limited.
630 Furthermore, there was not enough data for verifying the long-term vegetation
631 transition. Therefore, long-term field observations are necessary to improve the
632 reliability of the model using new techniques, such as remote sensing technology
633 and cross comparison with other models (Wang et al. 2014; Shifley et al. 2017).
634

635 **Cross-benefit evaluation**
636 Our results made it possible to compare scenarios using multiple indicators of
637 natural capital and ESs. Toward 2050, the results of this study suggested that
638 the intensity of forest and pasture land management had large impacts on natural
639 capital and ESs. Meanwhile, local stakeholders have multiple interests and
640 concerns not only sustainable ecosystem management but also social well-being
641 such as promoting decent works and establishing resilient cities announced in the
642 Sustainable Development Goals (United Nations 2015). To form a consensus on
643 ecological management, the output of the LANDIS–II model and other FLMs
644 should be linked with multiple benefits in terms of both social and ecological
645 systems.

646 In relation to the social system, the output of LANDIS-II can serve as an
647 input to ecosystem service models such as the InVEST model (Thompson et al.
648 2016a), and it can facilitate a holistic evaluation of ESs. In Japan, the interaction
649 between terrestrial and marine ecosystems has received national attention in the
650 form of the "Connect and Support Forests, Satoyama, Rivers and Sea" campaign
651 (Ministry of the Environment 2018). A coupling of the LANDIS-II and hydrological
652 models will also help explain the linkage between different types of ecosystems.

653 In terms of evaluation of ecological systems, biodiversity should be
654 evaluated from multiple perspectives. To evaluate floral change, we calculated
655 the diversity of land cover and the AGB in the watershed scale to evaluate the
656 landscape diversity and species diversity, respectively. The landscape diversity
657 probably impacts the quality of habitat for wildlife. The output of the LANDIS-II
658 model can be used to calculate the habitat suitability index (HSI) of various
659 species (e.g., De Jager et al. 2017). On the other hand, species diversity probably
660 reflects the diversity of ESs. The following are examples of species and their

661 characteristic ESs: Todo fir and Japanese larch provide both a timber provisioning

662 service (Fig. 8) and a carbon sequestration service (Table 4), Japanese white

663 birch provides a carbon sequestration service (Table 4). Therefore, it is expected

664 that the use of landscape and species diversity as comprehensive indicators of

665 regional-scale biodiversity and ESs diversity would be confirmed.

666 To evaluate the cross benefit, the effects of natural disturbances that

667 impact entire socio-ecological systems should also be taken into consideration.

668 In this study, the interactions among only human activities and flora was modeled

669 to simplify the ecological process in the region, while disturbance events such as

670 browsing by Hokkaido sika deer, forest fire, and wind throw are important

671 disturbances. For example, the growth of the Hokkaido sika deer population and

672 the damage caused by their browsing is one of the major problems facing

673 agriculture and forestry in the region (3.2 hundred-million-yen loss in 2014 which

674 means 4.5 % of GDP in Akkeshi town: 1 USD = 110 yen (Akkeshi town 2015;

675 Ministry of Agriculture, Forestry and Fisheries 2017b)). Local population decline

676 will also decrease the resilience in the face of those disturbances and the

677 magnitude of their impact may vary by scenario. The LANDIS-II modeling

678 community has developed extensions to simulate the effects of fire (He and

679 Mladenoff 1999), wind throw (Mladenoff and He 1999), and outbreaks of insects

680 and disease (Sturtevant et al. 2004), and extensions that consider the effect of

681 browsing ungulates are now in development (De Jager et al. 2017). The

682 simulation of impacts of those disturbances considering human intervention will

683 contribute to local decision making and sustainable design of landscape

684 management.

685

Conclusions

Our study conducted scenario analysis of natural capital and ESs focusing on underuse using LANDIS-II in the Bekanbeushi River Watershed, northern Japan. The assumptions of population distribution and capital preference which characterized the four future scenarios led to different consequences for natural capital and ESs. Population distribution affected the spatial allocation of abandoned pasture land and promoted the isolation of managed pasture land. The assumptions of capital preference largely affected the quantity of ESs, and the provisioning service and climate regulation service were both increased in the Ntr scenarios comparing with underuse situations expressed by the BaU and Prd scenarios.

These simulation results were usable to add quantitative information to the narrative scenarios provided by Saito et al. (2018) in terms of "Industrial structure and economy," "Infrastructure and policy" and "Culture and Value." This information concretized how future scenarios may affect not only ecological aspects but also lifestyles of local people and local industrial structure. Our process-based approach provided a better understanding of the relationships among social drivers, ecological processes and the consequences of natural capital and ESs, which will advance the quantitative scenario analysis in the regions in the context of future underuse trends.

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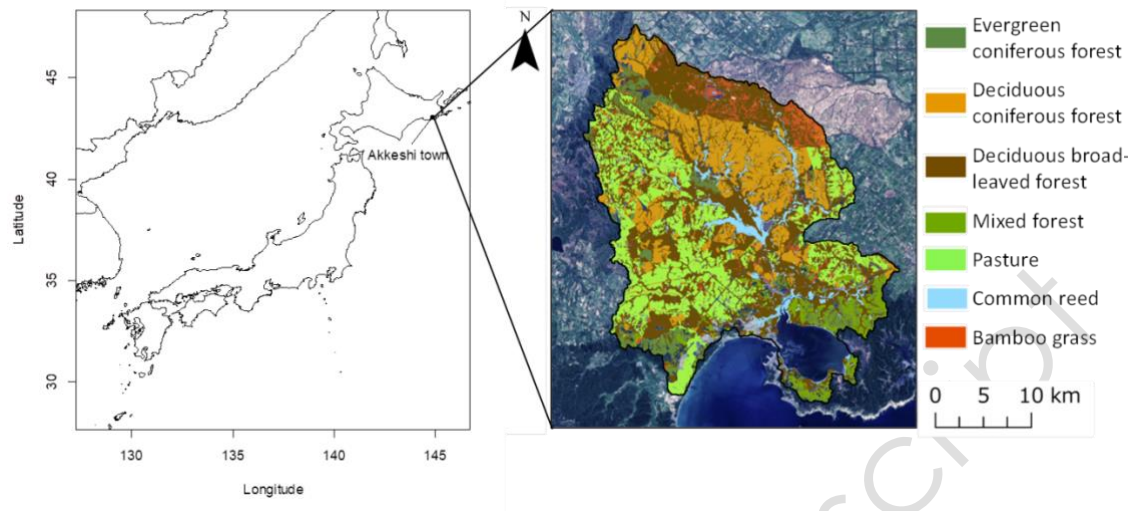974   DOI: 10.1016/j.chnaes.2009.01.001

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Figure

Fig. 1 Location of the study site and its vegetation and land cover.
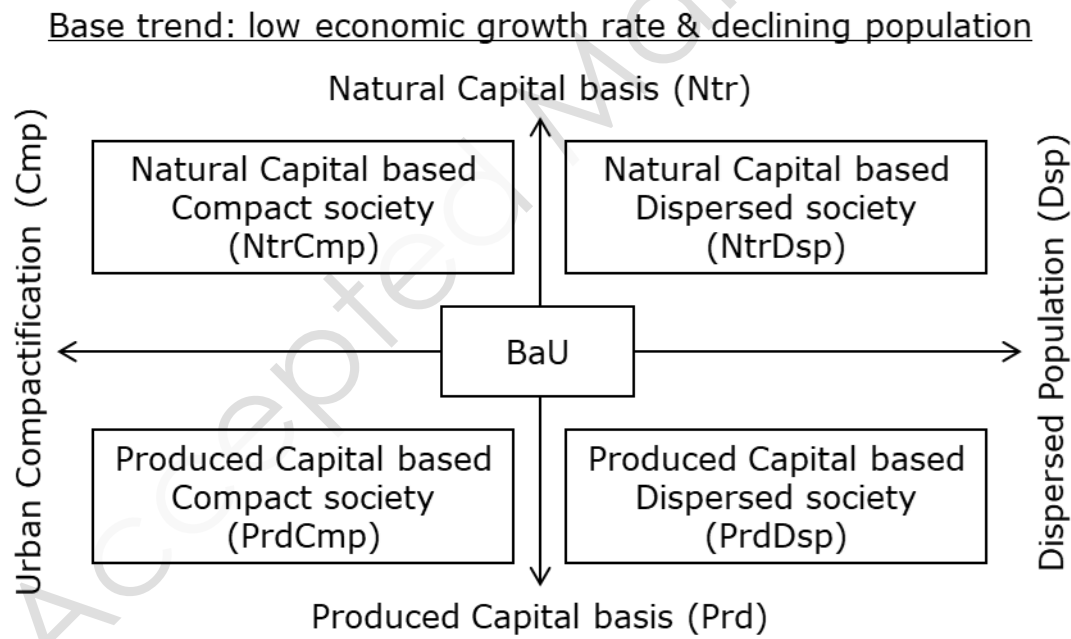
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Fig. 2 Four future scenarios on a national scale. The abbreviation of each

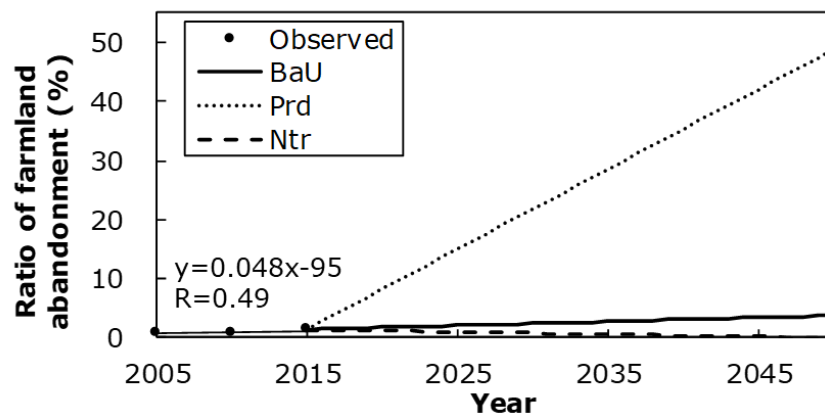scenario is shown in the bracket. For more details, see Saito et al. (2018).

978

Fig. 3 The trend and assumptions of the farmland abandonment ratio for each year.

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980

Population in the watershed:

8,604   4,118

Population in the watershed:

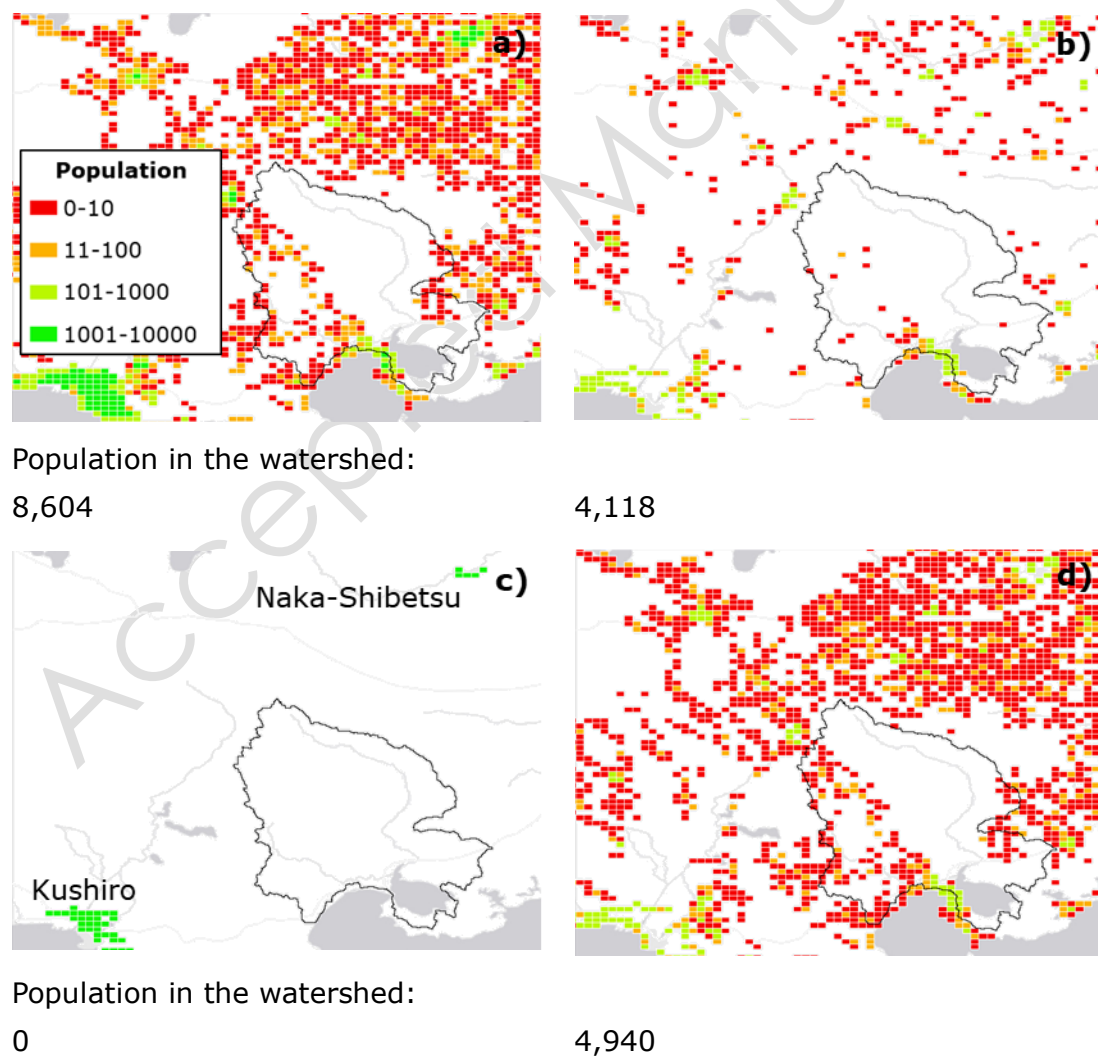0   4,940

Fig. 4 Distribution of residential population by scenarios. The black line shows

the boundary of the watershed, where (a) is the population distribution in 2010, and (b)-(d) indicate the population distribution under the BaU, Cmp, and Dsp scenarios in 2050, respectively.
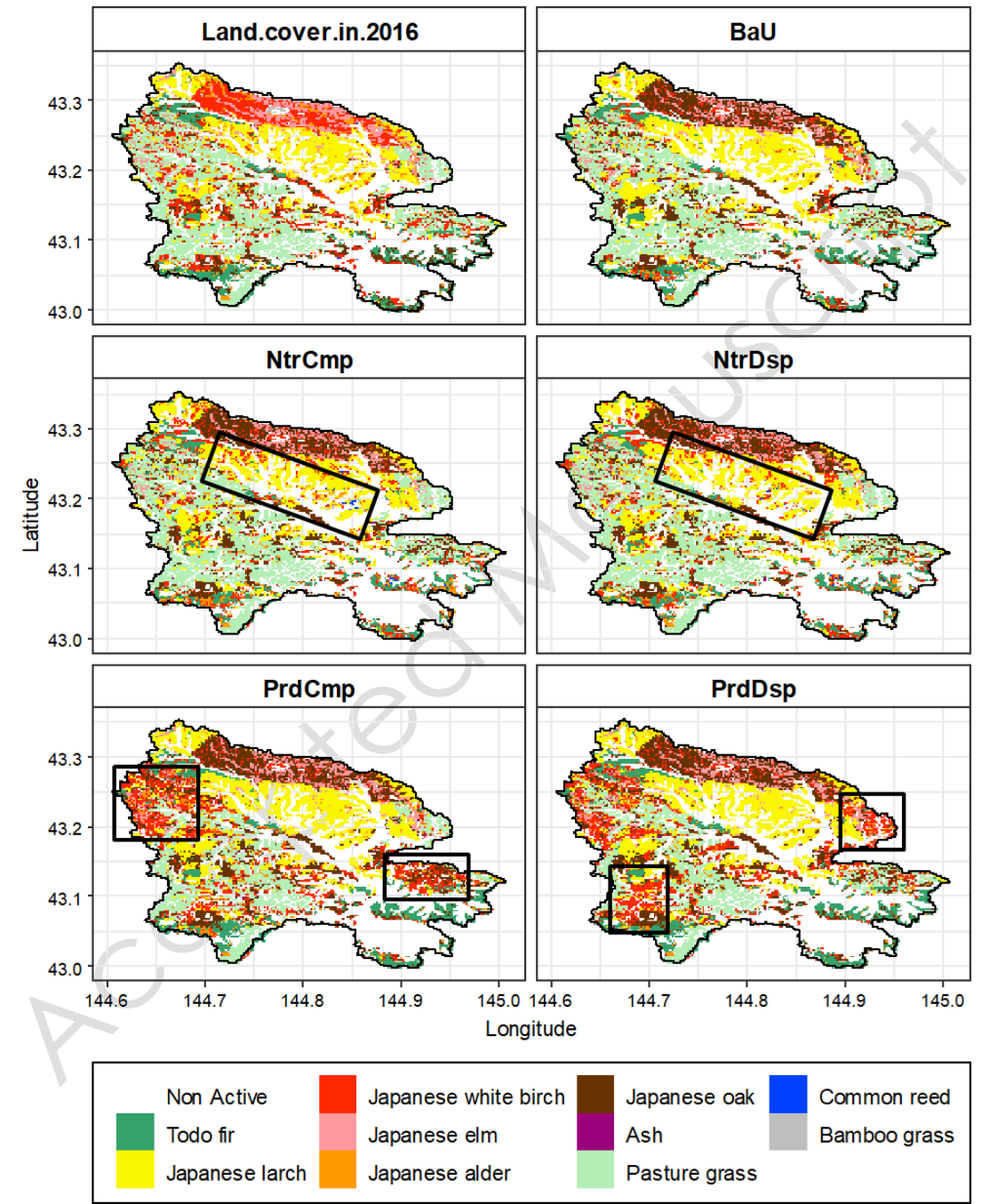
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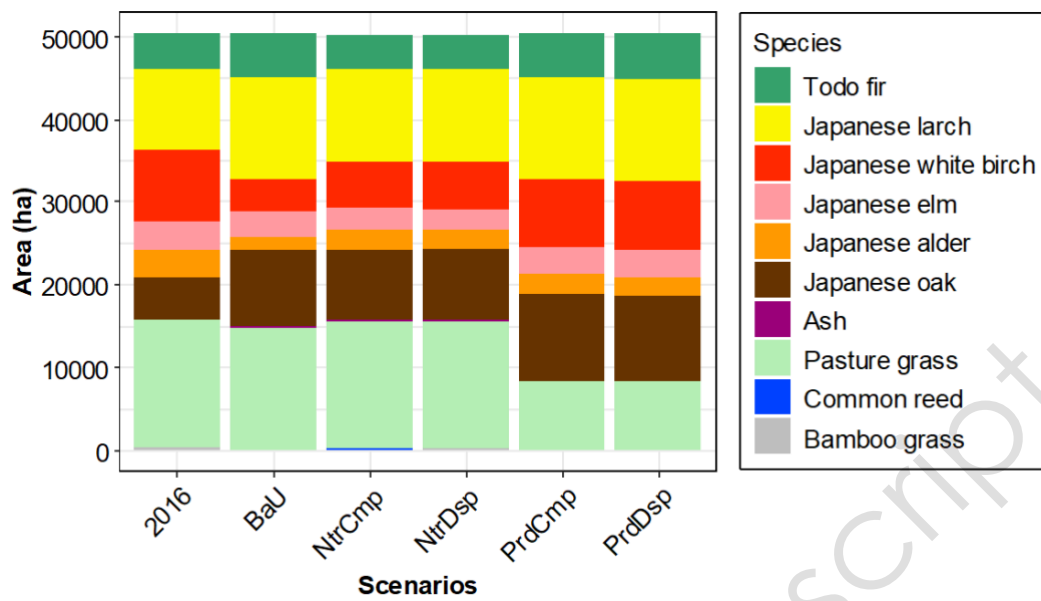**Fig. 5** The land cover maps in 2016 and 2050 of each scenario.

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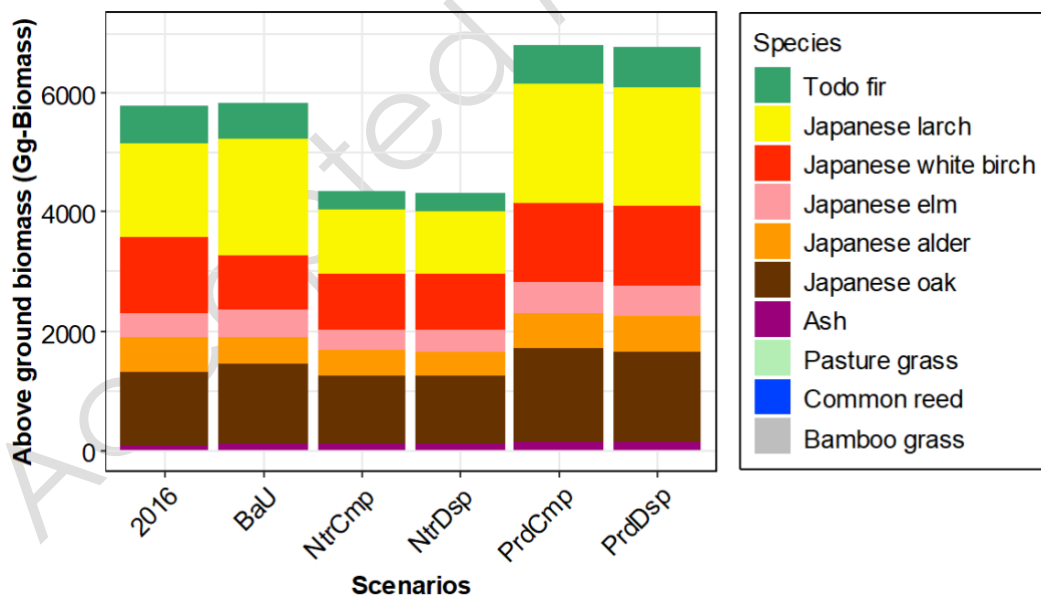**Fig. 6** The composition of land cover in 2016 and 2050 for each of the five scenarios.

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Fig. 7 The composition of aboveground biomass in 2016 and 2050 for each of the five scenarios.
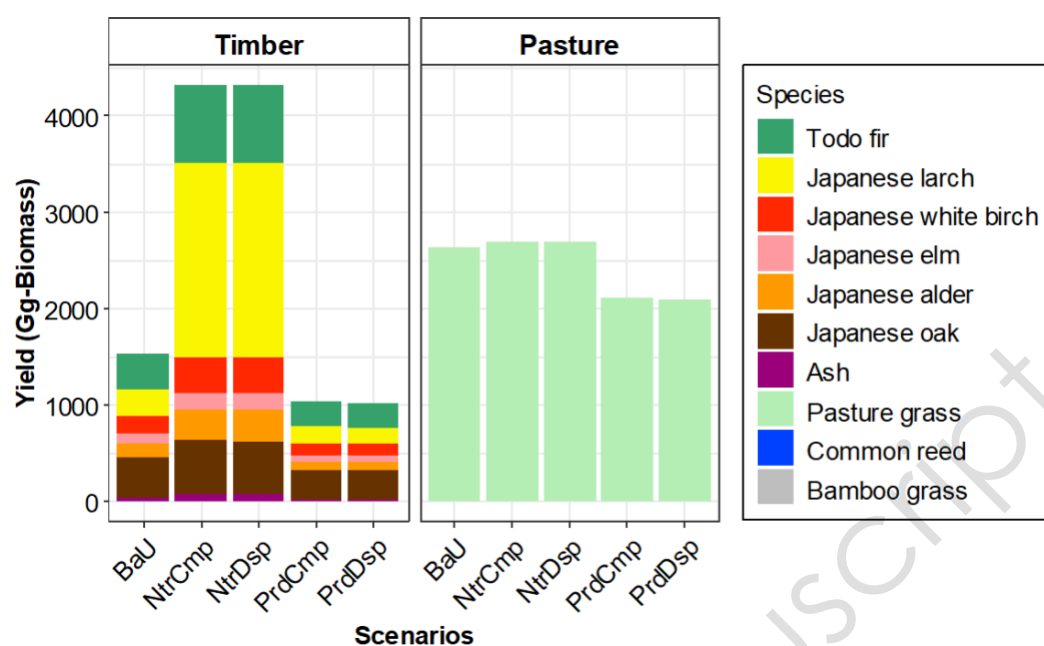
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Fig. 8 The projected total timber and pasture grass yield over 35 years.

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988

989 **Tables**

990 **Table 1** Management intensity setting by scenario.

Scenario name	Target species	Clear cutting and plantation			Clear cutting and natural regeneration			Thinning		
		(a)	(b)	(c)	(a)	(b)	(c)	(a)	(b)	(c)
2016	Todo fir:	0.025	0.045	0.075	0.025	0.030	0.050	1.30	1.40	1.30
	Larch:	0.025	0.045	0.075	0.030	0.025	0.050	1.30	1.40	1.30
BaU in	Todo fir:	0.025	0.045	0.075	0.025	0.030	0.050	1.30	1.40	1.30
2050	Larch:	0.025	0.045	0.075	0.030	0.025	0.050	1.30	1.40	1.30
Ntr in	Todo fir:	1.7	1.7	1.7	1.7	1.7	1.7	12.5	12.5	12.5
2050	Larch:	2.0	2.0	2.0	2.0	2.0	2.0	15.0	15.0	15.0
Prd in	Todo fir:	0	0	0	0	0	0	0	0	0
2050	Larch:	0	0	0	0	0	0	0	0	0

991 NOTE 1: The numbers are the proportion of annual managed cell in percent unit.

992 NOTE 2: (a) National forest, (b) Prefectural forest, and (c) Private forest

993

994 **Table 2** List of species used in the simulation.

Common names	Scientific Names
Japanese white birch	*Betula platyphylla* Sukaczev var. japonica (Miq.) H.Hara
Ash	*Fraxinus mandshurica* Rupr.
Japanese oak	*Quercus crispula* Blume
Japanese elm	*Ulmus davidiana* Planch. var. japonica (Rehder) Nakai
Japanese alder	*Alnus japonica* (Thunb.) Steud.
Japanese larch	*Larix kaempferi* (Lamb.) Carrière
Todo fir	*Abies sachalinensis* (F.Schmidt) Mast.
Pasture grass	-
Common reed	-
Bamboo grass	-

995

996

Table 3 The comparison of mean scores of all abandoned pasture lands during

the simulation. Variable names are defined by Eq. 1.

	Population (pop_i)	Distance to the nearest residential grid cell ($distToResi_i^{-1}$)	Distance to the nearest road ($distToRoad_i^{-1}$)	Mean slope ($meaSlope_i^{-1}$)	Mean Elevation ($meaElev_i^{-1}$)
PrdCmp	1.04	0.67	0.83	0.76	0.68
PrdDsp	1.01	0.89	0.78	0.77	0.67

NOTE: Red to blue indicates the high and low impact to Y_i in Eq. 1, respectively.

1000

1001

Table 4 The composition of the amount of carbon sequestration from 2016 to

2050 by land cover type.

Land cover type	Carbon sequestration for 35 years (Gg-C)				
	NtrCmp	NtrDsp	BaU	PrdCmp	PrdDsp
Todo fir	99	100	154	138	141
Japanese larch	586	586	246	215	216
Japanese white birch	396	393	306	666	640
Japanese elm	87	86	90	92	94
Japanese alder	109	107	81	105	97
Japanese oak	100	99	110	118	116
Ash	3	2	2	3	3
Pasture grass	780	781	768	615	614
Common reed	−3	−2	0	0	0
Bamboo grass	−2	−3	0	1	1
Total	2155	2149	1757	1953	1922

NOTE: A negative value indicates the carbon source, and a positive value

represents the carbon sink.

1 **Table 5** Scenario improvements by combining local future plans and our scenario simulation results based on PANCES

2 scenarios.

		NtrDsp	NtrCmp	PrdDsp	PrdCmp
Demographic structure		People live in the watershed, and the population in 2050 in the area is **1.19** times higher than the BaU scenario. Those local residents continue to manage the ecosystem actively.	People **move to the city center outside the watershed** by 2050. However, to manage the ecosystems in the watershed, agricultural and forestry workers come from nearby cities.	People live in the watershed, and the population in 2050 in the area is **1.19** times higher than the BaU scenario. The priority of ecosystem management is lower than NtrDsp because they rely on outside natural capital and ESs.	People **move to the city center outside the watershed** by 2050. Only the agricultural managers come to manage the pasture land for dairy farming, while the management is gradually abandoned.
Industrial structure and economy		Local residents or people who move to the nearest cities utilize the local food and timber products, and the self-sufficiency rate becomes higher. All pasture land is continuously managed for dairy farming and forestry. So the expected **pasture yield is the same level as the BaU scenario**. The forest management area (clear cutting) per year **increase to 1.7−2.0% yr⁻¹** and the **total timber yield is 2.8 times higher than the BaU scenario (Japanese larch and Todo fir are 7.3 and 2.2 times higher)**. The **species diversity is assumed to become 0.80, which is slightly higher than the BaU scenario**.		Local residents utilize imported food and timber production. In this situation, the self-sufficiency rate decreases. The pasture land abandonment progresses **due to the high elevation or steep-slope area**. **Pasture grass production has decreased to 80% compared to the BaU scenario**. **The timber yield decreases to 67%**, and people completely cease to manage the resources by 2050.	People who move to the nearest cities utilize imported food and timber production. In this situation, the self-sufficiency rate decreases. The pasture land abandonment progresses **in area far from settlements**. **Pasture grass production decreases to 80% compared to the BaU scenario**. **The timber yield is reduced to 67%**, and people completely cease to manage the resources by 2050.

Infrastructure and policy	Local managers or outside workers are promoted to activate the primary industry to utilize the local natural capital and ESs. For sustainable development of agriculture and forestry, the forest and pasture land is continuously managed through job creation.	There is no incentive to promote the primary industry.	
Culture and values	The local communities are vitalized by creation of jobs in the primary industry. The local natural capital will be conserved and **species diversity is higher than BaU scenario**. People will continue living in the watershed, and the contact with nature and wildlife will be maintained as traditional manners.	The local communities move to the city center, but the local natural capital will be conserved and **species diversity is higher than BaU scenario**.	The local communities are vitalized by the secondary or tertiary sector. **Japanese white birch forest increased** due to the farmland abandonment. This results in the **isolation of managed pasture land** and **slight increase in landscape diversity** than BaU and Ntr scenarios. This probably affect the habitat of wildlife such as Hokkaido sika deer and Brown bear. The risk of animal injury becomes higher than the NtrDsp.	There is no promotion to activate the local community. **Japanese white birch forest increased** due to the farmland abandonment. This results in the **isolation of managed pasture land** and **slight increase in landscape diversity** than BaU and Ntr scenarios. This probably affects the habitat of wildlife such as Hokkaido sika deer and Brown bear. People does not live in the region in 2050, while the risk of animal injury still exist for agricultural workers and it becomes higher than the NtrCmp.

1

2   NOTE: Improved points are highlighted in bold and underscore.

3