The Long-Term Trends of *Satoyama* Capital Stocks and Ecosystem Services; Case Study in Mt. Hakusan Biosphere Reserve and its Vicinity

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Abstract

We analyzed the long-term trends (from the 1950s to 2035) of Japanese "*satoyama* capital stocks" and ecosystem services in the Mt. Hakusan Biosphere Reserve, Japan. We estimated the spatial distribution of the human population in Hakusan City and chose grid squares where the human population was endangered. Many areas in *satoyama* regions in Japan will eventually become uninhabited. We made a list of natural and social capital stocks and ecosystem services in the area. We obtained the geographical distribution of *satoyama* areas that are in danger of disappearing. We also assessed the magnitude of threat and factors threatening the natural and social capital stocks and ecosystem services derived from the *satoyama* in this region. As a result, we predicted that the *satoyama* in the Mt. Hakusan Biosphere Reserve would be endangered because people with experience in "*dezukuri*" are nearly no longer existent. "*Dezukuri*" is defined as a traditional culture in which people stay in places distinct from their base settlements seasonally or temporally to cultivate farms. On the other hand, the number of people living in two places is increasing because many live in a rural city but visit the houses that their parents lived in to maintain them. They usually stay in or visit their second house on weekends. Such a new type of living in two places can prevent the extinction of *satoyama* capital stocks.

Key words: biodiversity, capital stock, depopulation, ecosystem service, Mt. Hakusan Biosphere Reserve, *satoyama*

1. Introduction

Biodiversity is defined as the existence of a variety of ecosystems, species and genotypes. People's life and culture in the *satoyama* and *satoumi* depend highly on biological productivity, particularly the provisioning of ecosystem services and cultural ecosystem services for their basic needs. The *satoyama* and *satoumi* provide a higher cultural identity and diversity within Japanese traditional culture than any other area (Duraiappah *et al*., 2012).

The term "*satoyama*" describes mosaic landscapes of different types of ecosystems: secondary forests, farmlands, irrigation ponds and grasslands, along with the local communities which manage the land to produce ecosystem services for human well-being (Duraiappah *et al*., 2012). The concept of "*satoyama*" has been extended to cover marine and coastal landscape, applying the term "*satoumi*" (UNU-IAS, 2011). The JSSA assessment (Duraiappah *et al*., 2012) defined "*satoyama*" as a mosaic of both terrestrial and aquatic ecosystems comprised of woodlands, plantations, grasslands, farmlands, pastures, irrigation ponds and canals, with an emphasis on the terrestrial ecosystems. *Satoyama* and *satoumi* landscapes are managed using a mix of traditional knowledge and modern science (JSSA-Hokushinetsu Cluster, 2010).

The *satoyama* and *satoumi* are characterized by natural, historical and cultural properties that are formed through the interaction of humans and nature. These include numerous resources which are either actually or potentially used. Starting from several centuries ago, knowledge of how to use these natural resources has been transferred from generation to generation, being modified and updated with new experience gradually accumulating in local communities.

Recently these landscapes and management systems have been rapidly changing, and the related ecosystem services are threatened due to various social, economic, political and technological factors. One reason is urbanization of the *satoyama* in lowlands near cities and conversion of *satoyama* landscapes from woodlands to

other land uses, resulting in degraded ecosystem functions (Ministry of the Environment, Japan, 2002). Another reason is depopulation of rural areas, resulting in abandonment of farmland and loss of human communities and traditional knowledge. Both of these factors cause the areas to lose their ecosystem services.

Ecosystem services are the benefits that people obtain from ecosystems (Millenium Ecosystem Assessment, 2005). Depopulation leads to the loss of ecosystem services that are used by people because nobody uses regional ecosystem services in areas where there are no people. Therefore our study focuses on the linkages between ecosystem services and human activities. Population dynamics is one of the indicators of human activities. We first analyze the endangerment of biodiversity and ecosystem services in the countryside between urban areas and mountainous areas.

The *satoyama* favors enhancement of lifestyles harmonious with nature. The *satoyama* also fosters a variety of life forms. These areas mainly comprise secondary forests around villages, together with rice fields, other agricultural plots, reservoirs and grasslands. These areas are also threatened by the reduction of traditional human activities and changes in lifestyles. The use of resources from secondary forests and secondary grasslands has almost disappeared due to their reduced economic value. On the other hand, the area of abandoned rice fields has increased. These trends will probably intensify. Such under-use of *satoyama* landscapes is recognized as the second major cause of degradation of Japanese biodiversity (Ministry of the Environment, Japan, 2002).

During the period of high economic growth in Japan from the 1950s to the 1970s, the socio-economic situation changed drastically. The main source of energy shifted from fuel woods to fossil fuels under the country's rapid industrialization. The human population migrated from rural areas to urban cities. Modern farming, using chemical pesticides and fertilizers, expanded. The shift in fuel sources decreased the prices of firewood and charcoal. After the 1970s, the use and management of secondary forests declined and therefore these forests transitioned to bush or bamboo forests. As the use and management of Japanese cedar forests declined (Nakashizuka *et al*., 2010), serious problems resulted, not only through the loss of the ecosystem function, but also by having an impact on human health with pollen allergies.

To resolve the *satoyama* and *satoumi* crisis, the *Satoyama* Initiative is being promoted by the Ministry of the Environment, Japan, and the United Nations University Institute of Advanced Studies (UNU-IAS). Its aim is to realize societies in harmony with nature and to build positive human-nature relationships (Anonymous, 2010).

Previous studies on evaluation of ecosystem services presumed economic evaluation by the contingent valuation method (CVM) to be the willingness to pay for the creation and sustenance of local communities and culture, or they chose cases of villages in the mountains, which still retained their traditional culture and landscape, and they measured the economic value of that conservation. The results contributed to the benefit transfer method, multiplying the number of villages on mountainsides (Yoshida, 1999). To evaluate ecosystem services in the *satoyama* or *satoumi*, we need to understand the local characteristics and current situation in *satoyama* or *satoumi* areas.

Depopulation is one of the major indirect driving forces with regard to ecosystem services in the *satoyama*. The effect of depopulation may be compensated for by multi-habitation. We found that multi-habitation is also one of the cultural traditions in the Mt. Hakusan area (Mt. Hakusan Biosphere Reserve, in Torigoe and part of Komastu City). We analyzed the effects of multi-habitation on the sustainability of traditional natural capital and ecosystem services in this area.

2. Methods

We categorized endemic natural capital stocks in the *satoyama* as geological, biological, social and economic stocks. These categories were originally used in the "endemic engineering" methods (Takebayashi, 1997), where social and economic stocks were originally called "historical-cultural" and "industrial stocks," respectively. Geological stocks mean outstanding landform elements such as beautiful rocks or popular wetlands and rivers, and exist on land and in the atmosphere and aquasphere. Biological stocks mean species or taxa that are actually or potentially used by local people as ecosystem services. They are subdivided into fungi, plants and animals. Social stocks mean human customs in lifestyles, heritages, monuments and vocabulary. They are divided into lifestyles, dwellings, foods, religion and language. Economic stocks relate to hunting, gathering, agriculture, forestry, fisheries and handicrafts.

We ascertained the current status of major endemic and regional capital stocks and ecosystem services. To achieve this goal, the scheme of our study is as follows. (a) analyzing population trends of Hakusan City in Ishikawa Prefecture, using 1 km x 1 km grid squares, (b) making an inventory of "*satoyama* capital stocks," (c) mapping the distributions of *satoyama* capital and their related ecosystem services, mainly consisting of vegetation and river basins, (d) summarizing *satoyama* capital stocks and ecosystem services in the case that a corresponding species is threatened or if local people that use these stocks have disappeared or are disappearing.

(a) Population trends affect the future of *satoyama* capital stocks and ecosystem services. We intensively analyzed population trends in Hakusan City, Ishikawa Prefecture. The Mt. Hakusan Biosphere Reserve was designated in 1980 as part of UNESCO's Man and the Biosphere Program. It includes the Shiramine, Oguchi and Yohinodani settlements in the Hakusan City municipality and parts of neighboring municipalities. Generally, settlements in hilly and mountainous areas of Japan are endangered due to depopulation.

We estimated the risk of population disappearance in the settlements of Hakusan City, including hilly and mountainous areas, using the National Census of 2005, 1km × 1km grid statistics edited by Sinfonica (a Japanese public foundation providing statistical consulting and analysis). At least five households are needed to maintain the presence of settlements in heavy snowfall areas (Fujisawa, 1982). Therefore, settlements where the number of households is less than five will probably disappear in the near future. We assume that five households is the equivalent of 13.9 people because the average number of people per household in the rural sections is 2.78, as calculated by the *2010 Japan Census* (Ministry of Internal Affairs and Communications, 2011). In addition, each settlement's center is assumed to be set within one grid square. Consequently, we judged that any grid square where the population was under 13.9 (=5×2.78) was in danger of disappearing.

We also estimated the population in each grid assuming multi-habitation to be promoted currently. We categorized each grid as a "city grid," "village grid" or "uninhabited grid" if the population of the grid was $\geq$ 4,000/km^2, 1-4,000/km^2 or 0, respectively. Practitioners of multi-habitation were placed in the village grid in equal numbers, N_p/n_v, where N_p is the number of practitioners and n_v is the number of village grids. In other words, N_p/n_v people were virtually added to the population of each village grid. We cannot know where practitioners go to in multi-habitation. Therefore, we assumed that they were placed equally in each village grid. Multi-habitation between Ishikawa and other prefectures was ignored because frequent round trips would be difficult. We supposed that five percent of the people who lived in the city grids of Ishikawa Prefecture practiced multi-habitation within the prefecture, because households with higher incomes, who are capable of it, account for 4.8% of the population (Ministry of Health, Labor and Welfare, Japan, 2011). Thus we set N_p as 5% of the total number of people who lived in the urban areas of Ishikawa Prefecture.

(b) We collected information about *satoyama* capital stocks through existing documents, interviews with people who had experience with "*dezukuri*" (Table 1), and inventory assessments in Shiramine, Oguchi and Yoshinodani villages. We listed, categorized and described *satoyama* capital stocks in Hakusan City. The full data were uploaded in Japanese (Hori, 2012). The Mt. Hakusan Biosphere Reserve was designated in 1980 by UNESCO's Man and the Biosphere Program. We counted the numbers of *satoyama* capital stocks related to each biome: forests, agricultural farms, inland waters and coastal-marine areas. We did not categorize geological stocks by biome.

(c) We categorized biological stocks as provisioning services or cultural services. Both services are important to people in the area for sustaining their life and regional culture. Local people receive the benefits (foods, other materials or specific knowledge) from biological stocks of endemic species. We did not list regulating services because it is difficult to identify the role of each species in ecosystem regulation.

We divided cultural services (CS) into two subcategories: "CS related to local community and culture" and "CS related to natural beauty, tourism and education." Regarding provisioning services and "CS related to local community and culture," we categorized these capital stocks as "extinct (EX)," "endangered (EN)," "vulnerable (VU)," "near threatened (NT)," "lower risk (LR)," "data deficient (DD)" and "not evaluated (NE)" by analogy to *Red List Categories* (IUCN, 2001) and "threatened local population (LP)" (Ministry of the Environment, Japan, 1997). The ranking of each ecosystem service fully depends on the ranking of the corresponding species that is used for it or referred to by the ecosystem service, although the magnitude of ranking of these services differed from the ranking of the corresponding species. For the ranking of threatened species we referred to *Ishikawa Red Data Book*s (Ishikawa Prefecture, 2009; 2010) and *Japanese Red List* (Ministry of the Environment, Japan, 2007), whichever showed the species to be more threatened if the ranking was split between these references. We ranked services as EX if the corresponding species was EX, CR or EN because these species could not be used as ecosystem services. A service was ranked as EN if the corresponding species was ranked as VU; as VU if it was ranked as NT or LP; and as LR if it was an endemic species.

Biodiversity is, however, not equal to ecosystem services. We also categorized *satoyama* capital other than provisioning services and cultural services related to local communities and culture according to the following criteria. The capital stock was ranked as EX if it was not locally used or the species corresponding to the capital stock was ranked as EX, CR or EN; as EN if it depended on conservation effort by museums or municipalities or if the corresponding species was VU; as VU if it was sustained by older people or the corresponding species was ranked as NT or LP; or as LR if it was still used by a local community or the corresponding species was probably endemic only to the Mt. Hakusan area. Many grids in this area showed a high risk of becoming uninhabited. Depopulation leads to loss of regional ecosystem services. A grid was DD if we had too few data to rank it but it was a source of concern. Otherwise, NE was chosen.

About "CS related to natural beauty, tourism and education," we gave these services the same ranking as the corresponding species listed in *Ishikawa Red Data Book*s (Ishikawa Prefecture, 2009; 2010).

(d) We mapped ecosystem services, overlapping vegetation and river basin layers. The satoyama in Hakusan City is located upstream in the Tedori River basin. The Mt. Hakusan area is characterized by strong winds and steep slopes.

We defined several social stocks in the Mt. Hakusan area. "*Dezukuri*" is a term for a lifestyle in which people stay seasonally or temporally and cultivate farms farther than a day trip from their base settlements. "*Nagihata*" means a kind of shifting cultivation, in which farmers

burn vegetation from uphill to downhill after cutting down trees in secondary forests. "*Ushikubi* spinning" is a local brand of silk fabric. "*Sakkuri*" refers to a fabric using a hemp warp. The welts are made of recycled yarns, nettle, ramie or other yarns. We also counted words that indicated special elements of local landscapes that were either still used or never used by the younger generations. "*Jige* (*boson*)" means the home village of a *dezukuri* base. "*Alpine plants*" are defined as grasslands with flourishing plants that mainly exist in mountainous areas.

The *satoyama* in Shiramine, Oguchi and Yoshinodani villages south of Hakusan City are surrounded by high mountains, forests and grasslands with alpine plants. There is rich biodiversity and geological diversity. There used to be many traditional customs like "*nagihata*" using natural resources.

3. Results

The left panel of Fig. 1 shows the population distribution of Hakusan City in 2005. As mentioned above, any grid square where the population was under 13.9 was considered endangered (see the red grids in this figure). We find many of these in the southern part of Hakusan City, which is a mountainous region.

The right panel of Fig. 1 shows the number of persons who lived in or stayed in each grid in 2005 when multi-habitation was promoted. Each village grid painted red or green gained a virtual 8.8 ($=N_p/n_v$) people by multi-habitation. Consequently, the number of endangered grids decreased by almost 50%, from 23 to 12. Most of these grids preserved by multi-habitation existed in southern Hakusan City.

Dezukuri is a traditional custom of multi-habitation. We analyzed the trends in satoyama capital stocks and ecosystem services, given the case of multi-habitation being promoted in the Mt. Hakusan area. We found 603 *satoyama* capital stocks and ecosystem services in Shiramine, Oguchi and Yoshinodani villages. Among these, there were 20 geological, 363 biological, 211 social and 9 economic stocks. Table 1 shows the numbers of biological stocks in each taxon that belongs to each biome. The *satoyama* natural capital of the Mt. Hakusan area depends mainly on forests. The sums of numbers of *satoyama* capital stocks in all biomes (376 biological and 226 and social stocks) were larger than the numbers of *satoyama* capital stocks (363 and 211) because some biological stocks (*e.g.*, amphibians) belonged to more than one biome.

Table 2 shows the number of biological stocks for each ecosystem service for each taxon. We collected stocks that mainly related to provisioning services or natural beauty, tourism and education. Biological stocks are found mainly in forests and mainly belong to plants Table 3 shows the number of capital stocks related to keywords that characterize the *satoyama* in the Mt. Hakusan area. *Satoyama* capital stocks and ecosystem services existed in the *dezukuri* bases. After the construction of the Dainichigawa Dam and Tedorigawa Dam, completed in 1967 and 1979, respectively, these capital stocks and services were lost or moved. These *dezukuri* and charcoal burning are rapidly lost when the rural population decreases. The *dezukuri* for Japanese cedar completely disappeared due to the timber's industry decline. The *dezukuri* for apiculture survived in 2011. Hunting bears or gathering wild plants continues because the home bases "*jige* (*boson*)" still exist. Although freshwater fishery such as white-spotted char (*Salvelinus*

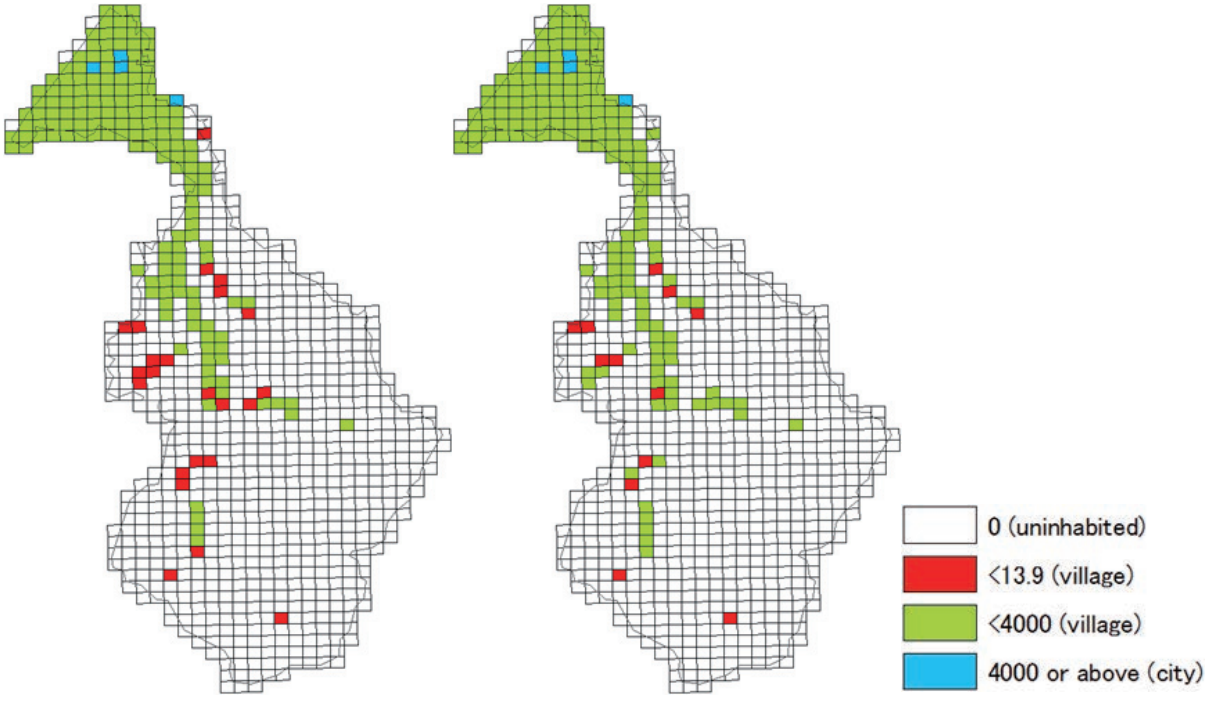

Fig. 1 The population of Hakusan City. Population densities of uninhabited, almost uninhabited, inhabited and urban grids are respectively 0, <14, 14-4000 and >4000.

Table 1 The number of biological stocks related to provisioning services.

	Forests	Agricultural farms	Inland waters	Coastal and marine	Total
Biological stocks					
Fungi	16	0	0	0	16
Plants	270	31	0	0	293
Animals	39	7	13	0	54
Subtotal*	325	38	13	0	376
Social stocks				2	35
Lifestyle	67	62	1	0	16
Foods	5	28	3	0	11
Dwellings	9	4	0	0	42
Religion	6	6	0	2	14
Language	22	7	1	0	9
Subtotal*	109	107	5	2	223
Economic stocks	7	2	2	0	9

* Total number of each taxon does not match the sum of each row because each stock may belong to more than one ecosystem.

Table 2 The number of stocks for each ecosystem service.

	Fungi	Plants	Animals	Total
Provisioning services	16	180	28	224
Cultural services related to local communities and culture	0	13	6	19
Cultural services related to natural beauty, tourism and education	0	107	19	126
Total*	16	293	54	363

* The total number of each taxon does not match the sum of numbers of ecosystem services for the same reason as in Table 1.

Table 3 The number of stocks related to characteristic keywords.

	Geological S.	Biological S.	Social S.	Economical S.	Total
Dezukuri	6	41	149	9	205
Hunting-gathering	0	125	9	3	137
Alpine plants	3	90	0	0	93
Nagihata	1	17	47	0	65
Mosaic	2	0	37	0	39
Charcoal burning	0	9	12	3	24
Ushikubi silk and *Sakkuri*	0	6	15	2	23
Geoparks	5	0	0	0	5

leucomaenis) also continues, the catch has decreased because of the population decrease caused by habitat fragmentation with dams.

Figure 2 shows the spatial distribution of ecosystem services. The distribution forms a mosaic structure. The locations of each cluster depend on vegetation type and river basin. *Dezukuri* and "hunting and gathering" were lost due to the construction of the two dams and the "Mt. Hakusan Super Road." Natural disasters also discouraged these activities. In addition, we compared the map of 2004 with the map in the 1950s. In the 1950s, there were places where *nagihata* cultivation used to occur, charcoal fuels were produced and reforestation was accomplished.

Endangered flora which is distributed higher than the beech forests in the Mt. Hakusan area includes 21 critically endangered or endangered species, and 49 vulnerable species that were listed by Ishikawa Prefecture, Japan in 2000 (Shimizu, 2005). These plants were gathered and used in natural medicines or as foliage plants. Detailed knowledge still exists for only 22 species among them on how to use these species.

4. Discussion

Satoyama capital stocks related to plants and forests accounted for the largest number of stocks in this area (Table 1). What biome has the largest number of capital stocks depends on the lifestyle, culture and identity of the local community (Table 2). The local identity in the Mt. Hakusan area appears to be related to forest and mountain ecosystems, therefore people in this area use wild species by hunting and gathering them (Table 3). Such hunting and gathering are traditional and perhaps

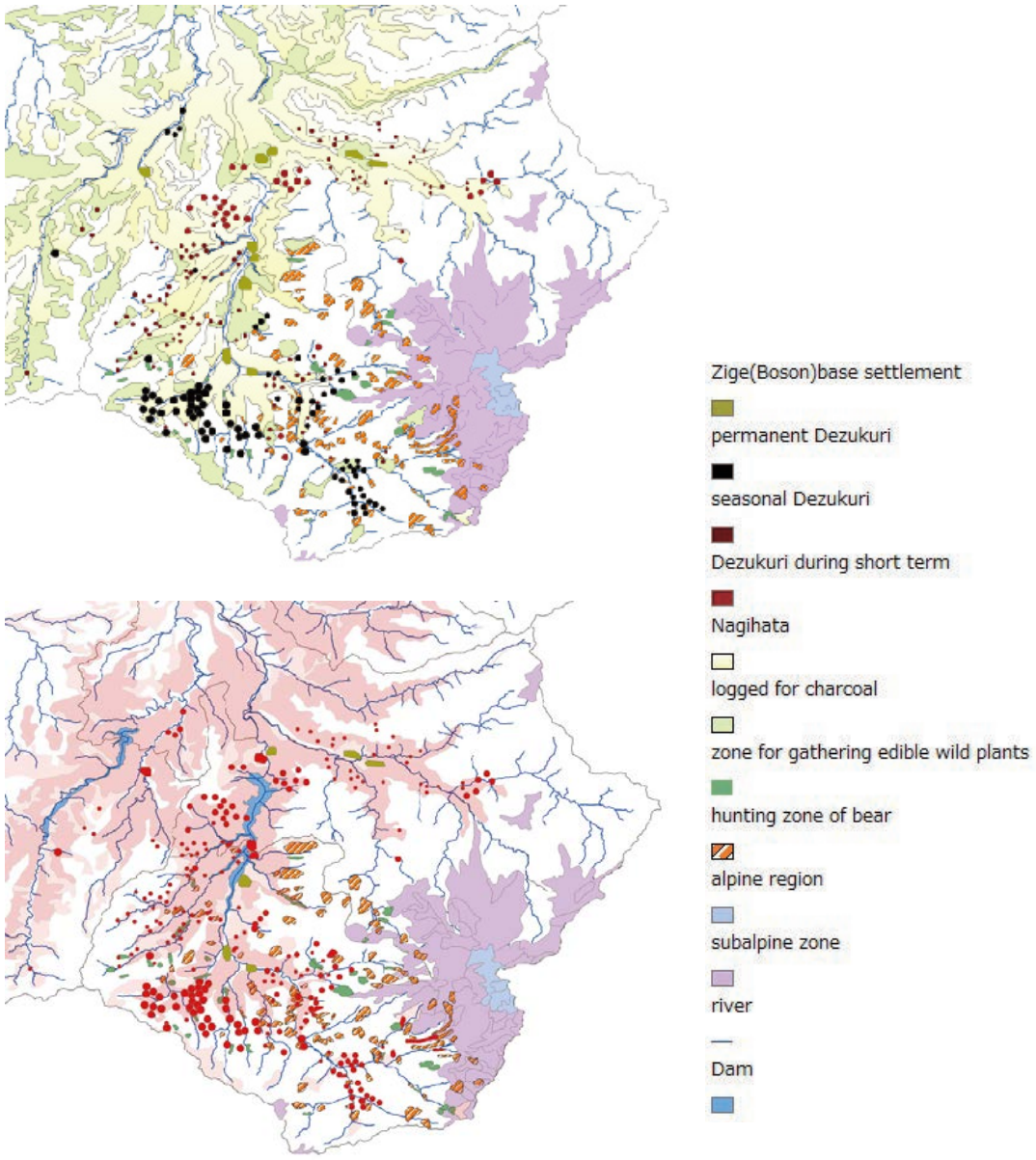

Fig. 2 The distribution of *satoyama* natural capital (above: 1950s, below: 2004).

"*Zige* (boson)" means a main settlement to which people return from *dezukuri* settlements; a "permanent *dezukuri*" is a settlement for *dezukuri* all year round. People in these engage mainly in sericulture. A "seasonal *dezukuri*" is a settlement for *dezukuri* only during the farming season. People there engage mainly in "*nagihata*" cultivation.
Dezukuri during a short term" is for *dezukuri* lasting one day to several weeks. People there engage mainly in logging or tending Japanese cedar plantations.
We also indicate "zones for gathering edible wild plants," including medicinal herbs in the "alpine zone" and "subalpine zone," and "hunting zones for bear" as regional ecosystem services which people use.
The red spots and areas in the lower panel indicate capital stocks that have disappeared.

sustainable customs. On the other hand, agricultural ecosystems might be the largest in *satoyama* areas located in lowland areas.

We found no biological stocks from marine ecosystems in the Mt. Hakusan area. These would be trivial in mountain areas. We did find, however, two social stocks related to marine ecosystems (Table 1): "*konka*" sardine/herring and "*omo*" herring. "*Konka*" means fermented and salted. "*Omo*" herring means dried herring complete with bones and heads. In central Japan, including Kyoto, "*mikaki*" herring is a popular traditional food item. It is dried herring without the head, bones or internal organs. This suggests that the traditional life in the Mt. Hakusan area mainly depended on local natural resources with few fisheries products.

Table 1 also shows that the *satoyama* natural capital in the Mt. Hakusan area mainly comprised secondary forests around villages, together with *nagihata* (shifting cultivation) and *dezukuri* (multi-habitation). Shifting cultivation in Japan is known by many local names like "*nagihata*," "*kano*," "*nagino*" and "*yabo*." Although shifting cultivation is a key component of the *satoyama* in hilly-mountainous areas, it has almost been lost throughout Japan. Only a few people continued these

traditions in the Mt. Hakusan area.

The ecosystems services associated with "CS related to natural beauty, tourism and education" depend on wild plants, including alpine and subalpine plants (Tables 3 and 4). These ecosystem services are linked to biodiversity. Therefore "CS related to natural beauty, tourism and education" goes extinct through loss of biodiversity.

Finally, we examined the differences between Mt. Hakusan and other areas. There are many local words that imply mosaic landscape. For instance, "*mutsushi,*" which means good land for "*nagihata*" cultivation; "*arashi*," which has the opposite meaning of "*mutsushi*"; "*kya-chi*," which means a farm around a "*dezukuri*" house; and "*na-bata*," which means farmland that is rich in edible wild plants, and is a good spot for bear-hunting. In Table 4, all 37 social stocks that relate to mosaic landscapes have special words. This suggests that people recognize the importance of mosaic landscapes. On the other hand, it is difficult to evaluate the role of the mosaic structure by counting the number of capital stocks in the Mt. Hakusan area.

Biodiversity is maintained by the dynamic properties of biogeological processes. Over time scales of decades or centuries, many landscapes are altered by natural disturbances such as landslides, floods and forest fires, that lead to mosaics of successional patches of different ages. Biodiversity is maintained as a mosaic structure that is balanced between succession and natural disturbance (Christensen *et al*., 1996).

It is difficult to evaluate the quantitative degradation of ecosystem services. It would probably require joint research of socioeconomic and ecological surveys. We have just shown spatial distributions of *satoyama* natural capital in the 1950s and the lost capital stocks as of 2004 by surveying documents, interviewing inhabitants and assessing inventory. *Dezukuri* is one of the most critical keypoints to the survival of *satoyama* capital stocks in the Mt. Hakusan area. *Dezukuri* was almost lost after the construction of the two dams and the road through the mountain forests. Natural capital and ecosystem services that are used only at endangered *dezukuri* bases and *jige* villages will disappear. As mentioned above, multi-habitation may be effective in conservation of *satoyama* capital if younger people learn and succeed to the culture and usage of ecosystem services used in *dezukuri* customs. Now people who have experience in *dezukuri* customs are in their 60s or older. Therefore natural capital related to *dezukuri* is critically endangered. In addition, several limitations to our research arose when we gathered data on satoyama capital stocks and ecosystem services, because people stopped practicing *nagihata* in the 1970s in these areas.

We have highlighted the endangered ecosystem services and natural capital stocks of the *satoyama* in the Mt. Hakusan area, including sustainable use of natural resources, to identify a new commons for a nature-harmonious society in *satoyama* areas and solutions from our analysis of the population, and this knowledge can be applied to similar spots throughout Japan.

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Table 4 The number of biological, social and economical stocks for each rank of endangerment.

	Disappeared	Endangered	Vulnerable	Near threatened	Data deficient	Not evaluated	Total
Geological stocks	0	0	0	0	0	21	21
Biological stocks							
Fungi	1	0	3	7	0	5	16
Plants	20	47	42	62	38	84	293
Animals	16	9	1	8	2	18	54
Social stocks							
Lifestyle	90	3	3	0	8	2	106
Foods	11	1	2	13	2	7	36
Dwellings	15	0	0	0	1	0	16
Religion	4	1	0	3	1	2	11
Language	3	1	1	0	37	0	42
Economic stocks	0	4	3	1	0	1	9
Total	160	66	55	94	89	139	583

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