

Mapping and characterizing ecosystem services of social–ecological production landscapes: case study of Noto, Japan

Shizuka Hashimoto · Shogo Nakamura ·
Osamu Saito · Ryo Kohsaka · Chiho Kamiyama ·
Mitsuyuki Tomiyoshi · Tomoya Kishioka

Received: 5 October 2014 / Accepted: 3 December 2014 / Published online: 20 December 2014
© Springer Japan 2014

Abstract Improving our understanding about ecosystem production, function, and services is central to balancing both conservation and development goals while enhancing human well-being. This study builds a scientific basis for conservation and development planning by exploring the types, abundance, and spatial variation in ecosystem services in the Noto Peninsula of Japan, a Globally Important Agricultural Heritage Systems. Although the Noto Peninsula is recognized as an important social–ecological production landscape, limited quantitative information about ecosystem services is available. This study evaluates and maps ecosystem services and explores their spatial variation using original data obtained through questionnaire surveys and secondary data from literature, statistics, and geographic information systems. The hilly and mountainous geography of the Noto Peninsula and its remoteness from large consumption markets work as constraints for agricultural provisioning services by limiting water

resources, labor productivity, and choice of economically viable crops. However, the rich forests, and marine and coastal resources provide various economic opportunities for forest-, fishery-, and livestock-related provisioning services. Geographical conditions such as land use and cover type also play an important role in differentiating the spatial variation of regulating services, a variation that starkly differs to distribution patterns in other areas. Unlike provisioning and regulating services, natural and artificial landscape components including traditional and cultural constructions such as shrines and temples work as an anchor to help people appreciate intangible and tangible cultural services, linking different services to specific locales across the Noto Peninsula.

Keywords Social–ecological production landscape · Ecosystem services · Spatial variation · Landscape planning · Geographic information system (GIS) · Noto Peninsula

Handled by Iris C. Bohnet, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia.

S. Hashimoto (✉) · T. Kishioka
Graduate School of Global Environmental Studies, Kyoto University, Kitashirakawa-oiwakecho, Sakyo, Kyoto, Japan
e-mail: hash@kais.kyoto-u.ac.jp

S. Nakamura
Center for Social and Environmental Systems Research,
National Institute for Environmental Studies, Tsukuba, Japan

O. Saito · C. Kamiyama
UNU Institute for the Advanced Studies of Sustainability,
Tokyo, Japan

R. Kohsaka · M. Tomiyoshi
Graduate School of Human and Socio-Environmental Studies,
Kanazawa University, Kanazawa, Japan

Introduction

Attention to the concept of ecosystem services has been growing in the policy and scientific communities over the past decade. The Millennium Ecosystem Assessment (MA), an international assessment of the world's ecosystem services involving over 1,300 scientists around the world, emphasized multiple benefits of ecosystem services by linking ecosystem function and human well-being. A conclusion of the MA was that 15 out of 24 ecosystem services assessed globally were declining, which would become a major barrier to achieving the Millennium Development Goals (MA 2005). The seminal work of MA helped to advance the conservation of biodiversity and

ecosystems by producing a bundle of ecosystem services for human well-being. Its sub-global assessments (SGAs) demonstrated the importance of measuring and mapping various ecosystem services for analyzing the conditions and trends of those services and their impacts on human well-being at local scales (MA 2005; Fisher et al. 2009), although there are challenges in evaluating ecosystem services, especially indicators of regulating cultural services (Layke et al. 2012).

A general consensus exists on the need to evaluate ecosystem services to improve decision making and planning and to meet different development objectives, although a widely accepted approach to planning ecosystem services has yet to be developed (Egoh et al. 2007; Barrena et al. 2014). Valuation and mapping of ecosystem services, for instance, help define high priority areas for environmental and conservation planning (Raymond et al. 2009). These ecosystem services improve our understanding about the potential trade-offs of ecosystem services, which result from conflicting development practices (Shoyama and Yamagata 2014). Finer scale analyses of ecosystem services is of crucial importance for dealing with specific areas (Naidoo et al. 2008).

Understanding ecosystem production, function, and ecosystem services is a central to balancing conservation and development goals, and integration of scientific findings into policies enables achievement of conservation targets while improving human well-being (Tallis et al. 2008; Daily et al. 2009). Recent establishment of the Intergovernmental Science-Policy Platform for Biodiversity and Ecosystem Services (IPBES) in April 2012 will further increase public awareness of the biodiversity and ecosystem services through its four functions: assessment, policy support, knowledge generation, and capacity building. The EU Biodiversity Strategy to 2020 mandates that local governments integrate the value of ecosystem services into environmental accounting and reporting (Morri et al. 2014). The National Biodiversity Strategy of Japan 2012–2020 formulated a roadmap for achieving Aichi Biodiversity Targets, which pronounced the importance of economically evaluating and visualizing ecosystem services.

The Japan Satoyama–Satoumi Assessment (JSSA) initiated in late 2006 as follow-up SGAs was the first in Japan to have a multi-scale approach. Satoyama and satoumi indicate a mosaic of different ecosystems including terrestrial, coastal, and marine ecosystems along with human settlements, which have long provided various ecosystem services for human well-being and are internationally known types of social–ecological production landscapes (Indrawan et al. 2014). The objective of JSSA was to improve understanding of the relationship between satoyama and satoumi with biodiversity, ecosystem services,

and human well-being, and to provide a credible scientific basis to policymakers for decision making (Duraiappah et al. 2012). The JSSA focused on nationwide conditions and trends of biodiversity and ecosystem services, while the cluster assessment explored the same aspects at six geographically delineated areas across Japan inviting various stakeholders such as government officials and NGOs. One of the striking results of the JSSA was that satoyama and satoumi have altered significantly over the past 50 years, impairing the sustainable supply of ecosystem services and having potentially negative impacts on human well-being (Duraiappah et al. 2012).

Evaluation and mapping of the regulating and cultural ecosystem services were major challenges faced in the process of JSSA. Although various statistics were available for most of the provisioning services at different spatial scales, data were scarce on the conditions of the regulating and cultural services. In addition, although recognition of the concept of ecosystem services is rapidly growing, since the publication of JSSA only a few studies have conducted an assessment of ecosystem services at local scales such as forest reserves and watersheds (Ninan and Inoue 2013; Shoyama and Yamagata 2014). In view of sustainability science that probes social–ecological systems in which natural and social systems are intricately linked (Ostrom 2009), the valuing and mapping of ecosystem services produced by a social–ecological production landscape is an important challenge for the conservation and the sustainable use of biodiversity and ecosystems.

The Noto Peninsula is recognized as an important social–ecological production landscape of Japan, consisting of dynamic mosaics of landscapes that have been shaped over the years through the interactions between people and nature in various ways; maintaining biodiversity while providing a bundle of ecosystem services for human well-being (Gu and Subramanian 2014). Noto has been designated as one of the Globally Important Agricultural Heritage Systems (GIAHS), by the Food and Agriculture Organization of the United Nations. GIAHS is an international initiative to foster dynamic conservation of traditional and unique agricultural systems and their associated biodiversity, knowledge systems, and cultures by establishing global and national recognition. This initiative complements the limitations of conventional approaches such as those for protected areas (Harrop 2007; Koohafkan and Jane 2011). Although in 2014 there were 31 GIAHS sites across the world, the sites in which ecosystem functioning and/or their services were extensively verified is still limited such as rice–fish coculture systems in Qingtian county, China (Xie et al. 2011), and cultural values of Chiloé Island, Chile (Barrena et al. 2014; Nahuelhual et al. 2014). Hence the need for further efforts exists to improve understanding about ecosystem services and their

contribution to human well-being in different social–ecological settings. Most of the information collected to register the Noto Peninsula on the GIAHS is in the form of qualitative descriptions that illustrate its characteristics from the aspect of the GIAHS selection criteria (FAO 2011). Quantitative information about ecosystem services arising from the Noto Peninsula is limited, which makes it difficult for policy makers to take strategic and effective conservation actions toward its sustainable use and management. This study aims to improve our understanding of types, abundance and spatial variation of ecosystem services arising from the Noto Peninsula of Japan by valuing and mapping ecosystem services using a geographic information system (GIS).

Study area

The Noto Peninsula is located in the north of the Ishikawa prefecture, facing the Sea of Japan (Fig. 1). People of Noto originally lived on hunting and gathering dating back over 2,100 years, and paddy farming was introduced over 1,300 years ago, which brought various traditional and cultural assets such as indigenous animism, and hereditary resource uses, rights, and practices. The peninsula is

dominated by hilly and mountainous areas, interspersed with rice paddy fields and dry crop fields (Fig. 2a, b). Although Noto has been categorized as a less-favored area in agricultural policy, it has formed unique social–ecological production landscapes in a combination of satoyama and satoumi. Satoyama comprises secondary woodlands, plantations, grasslands, farmlands, pastures, irrigation ponds, and canals, whereas satoumi comprises seashore, rocky shore, tidal flats, and seaweed beds; these combined landscapes allow the integration of farming with fishing and forestry (FAO 2011).

However, the sustainability of Noto’s social–ecological production landscapes has recently been called into question due to the rapid depopulation and aging of the local community, which is gradually breaking down the balance between human and nature, causing, for instance, the abandonment of farmland and forests, and increasing the incidence of human–wildlife conflict. Although rich fishing resources around the peninsula have nurtured the fishing industry of Noto over time, the lack of large, flat plains has made it difficult for Noto to improve agricultural productivity through mechanization and farmland consolidation. The population of Noto has gradually decreased since the mid-1950s due to the limited job opportunities caused by stagnating agriculture and forestry as well as remoteness

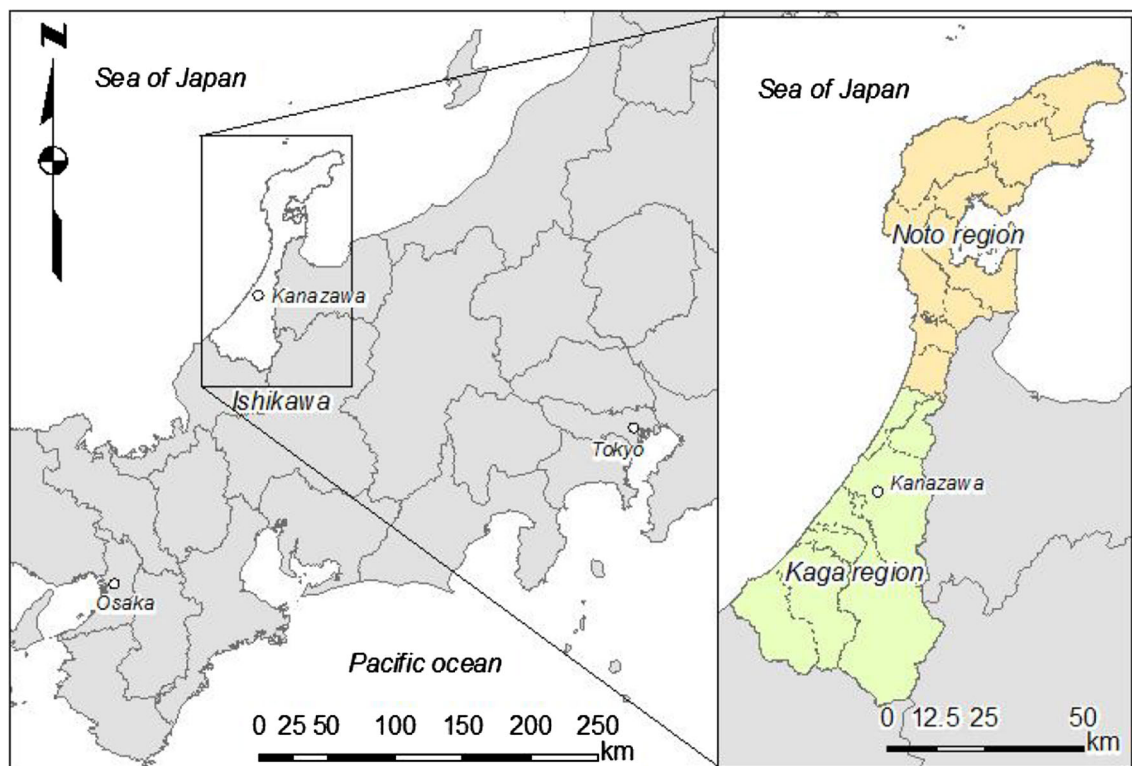


Fig. 1 Location map of Ishikawa prefecture, Noto and Kaga regions. Dotted lines on the map located in the right-hand box show the boundaries of the municipalities)

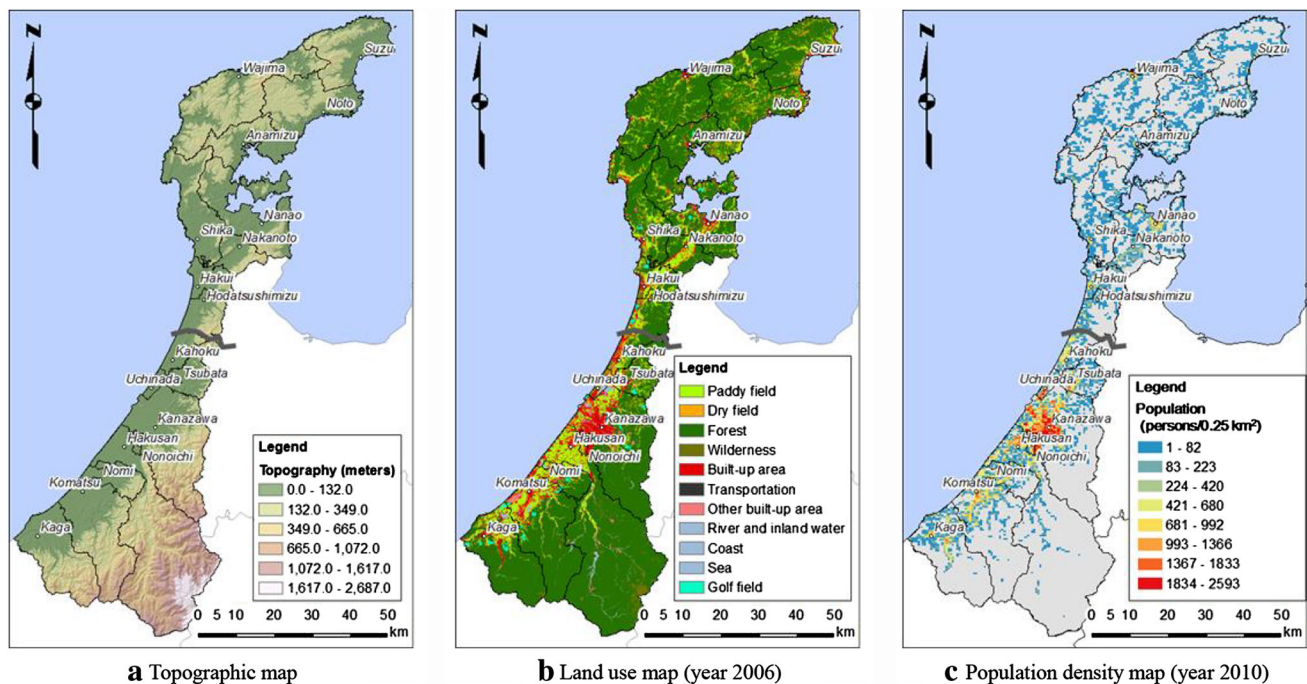


Fig. 2 Geographical characteristics of Ishikawa prefecture. *Gray thick lines* between Houdatsushimizu and Kahoku in each map represents a boundary between Noto (northern side, comprising 9 municipalities) and Kaga (southern side, comprising 10 municipalities) regions

from large cities (Fig. 2c). The ongoing trend of aging in local communities has further aggravated this situation; the percentage of the total population aged 65 or over has been increasing, and reached 34 % in 2011, which is much higher than both the national and prefectural averages of 23 and 24 %, respectively. This has resulted in a rapid increase in abandoned forests and farmlands, triggering the spread of agricultural damage by wildlife.

Materials and methods

Noto's satoyama and satoumi have been shaped over time by the evolving needs of the time, producing a bundle of ecosystem services for human well-being. To develop a site-specific conservation and development strategy for achieving sustainable use and management of Noto's social–ecological production landscapes, valuation and mapping of nature's benefit to people or ecosystem services is of crucial importance (Daily et al. 2009; Indrawan et al. 2014). In this regard, quantitative valuation needs to identify potential trade-offs between ecosystem services by examining multiple ecosystem services including provisioning, regulating, and cultural services (Tallis and Polasky 2009; Raudsepp-Hearne et al. 2010). Quantitative valuation by mapping with GIS will help to characterize spatial variation of different services and to identify hot-spots that need special attention with regard to planning

conservation and development as well as to designing new policy and regulation schemes (Johnson et al. 2012; van Riper et al. 2012; Qiu and Turner 2013). The categories of ecosystem services in this study are in line with the MA and JSSA, but pay special attention to provisioning, regulating, and cultural services, as they have relatively direct and short-term impacts on human well-being (MA 2005; Duraiappah et al. 2012). Supporting services such as nutrient cycling and soil formation were not evaluated in this study as they are biophysical structure and processes underpinning to the other service categories (MA 2005), which, if included in the evaluation, would lead to potential double counting of ecosystem services (de Groot et al. 2010; Hein et al. 2006).

This study uses both original data obtained through questionnaire surveys and secondary data from literature, statistics, and geographical information. The inventory of ecosystem services evaluated in this study is shown in Table 1, which is an elaboration of information from JSSA's cluster report (Duraiappah et al. 2012) and the GIAHS proposal (FAO 2011). The assessment of provisioning, regulating, and cultural services was carried out with the ecosystem services inventory.

Although agriculture and forestry contribute to produce a variety of ecosystem services along with provisioning services, these services tend to be underappreciated because most of them are non-market services (Power 2010). However, there has been a growing recognition in

Table 1 Ecosystem services of the Noto Peninsula evaluated in this study

Ecosystem services		Unit	Valuation method
Provisioning			
Agriculture	Paddy field	Ha	Prefectural statistics
	Dry-field	Ha	
	Rice	tons/year	
	Vegetables (8 items)	tons/year	
Forestry	Forest area	Ha	
	Timber	m ³ /year	
Fishery	Fish	tons/year	
	Shell fish	tons/year	
	Seaweed	tons/year	
Livestock	Dairy cow	Population	
	Beef cattle	Population	
	Pig	Population	
	Egg-laying hen	Population	
Regulating			
Atmospheric	CO ₂ absorption	tons-CO ₂ /year	Estimated with geographic information (see Table 6)
Water	Flood mitigation	m ³ /year	
	Water retention	m ³ /year	
Soil	Soil erosion control	m ³ /year	
Cultural			
Esthetic values		points/Ha	Social survey of perceived value of cultural services
Educational value		points/Ha	
Recreational value		points/Ha	
Spiritual and religious value		points/Ha	
Historical heritage value		points/Ha	
Therapeutic value		points/Ha	
Cultural heritage value		points/Ha	

Japan, especially since the late 1990s, that agriculture and forestry provide multiple positive externalities for the public, often referred to as multifunctionalities of agriculture and forestry. The appreciation of the multifunctionality of paddy rice cultivation such as water retention, flood regulation, and recreation is also observed in other monsoonal Asian countries (Huang et al. 2006; Matsuno et al. 2006), as a focus issue for international trade negotiations over the past decades. Recently, rice paddies are recognized as wetland systems by the Convention on Wetlands (Resolution X.31), garnering increasing attention from conservationists (Natuhara 2013). Although efforts have been made to economically evaluate ecosystem services arising from agricultural and forest ecosystems (Chang and Ying 2005; Aizaki et al. 2006; Yoshida and Hayashi 2012),

Table 2 Overview of the questionnaire surveys with target area, sample size, survey period, delivery method, and number of responses

	Noto Peninsula	Kanazawa city
Target and number of questionnaire delivered	7,068 residents of nine municipalities of the Noto Peninsula	1,864 residents of the Kanazawa city
Survey period	October 1 to 29, 2013	September 9 to October 9, 2013
Delivery method	Combination of postal mail and hand-deliver	Postal mail
Number of responses	1,662 (20.8 %)	138 (7.5 %)

less efforts have been made to identify and characterize the spatial variation of those services.

In this study, agricultural, fishery and forest statistics from Ishikawa prefecture were mainly used to assess provisioning services produced or obtained in the municipalities of Noto, whereas geographic information such as land use, vegetation, and precipitation was used to assess regulating services. The valuation of biophysical quantity of regulating services with GIS in this study was built on the work by the Science Council of Japan (SCJ) (SCJ 2001) and the National Research Institute of Agricultural Economics (NRIAE) (NRIAE 1998). Flood mitigation, water retention, soil erosion control, and CO₂ absorption were evaluated and mapped as regulating services. To characterize abundance and spatial variation of the provisioning and regulating services produced in Noto, all of the 19 municipalities of Ishikawa prefecture, of which 9 are in Noto and 10 are in Kaga region, were subjected to data collection and statistical analysis (SPSS 19.0).

Cultural services, or “non-material or intangible benefits people obtain from ecosystems”, were often overlooked in past assessments due to the difficulties associated with valuation and visualization of intangible benefits, with few exceptions that employ economic valuation (MA 2005). Various efforts were made in recent years for developing and applying methodologies to value and map cultural services in a quantitative manner, complementing limitations in economic valuation (Hernández-Morcillo et al. 2013; Milcu et al. 2013). For assessing cultural services of Noto, a questionnaire survey was employed, targeting randomly sampled residents and visitors of Noto Peninsula (Table 2). The questionnaire with a map of Noto Peninsula was built on previous studies that employed a mapping exercise for evaluating cultural services (Brown 2004; Alessa et al. 2008; van Riper et al. 2012; Nahuelhual et al. 2014). Our questionnaire assessed preferences and perceptions of respondents about seven cultural services: esthetic, educational, recreational, spiritual and religious,

Table 3 Typology of perceived value of cultural services used in Noto Peninsula case study

Esthetic value	Areas valued for the beautiful scenery
Educational value	Areas valued because we can learn about the nature
Recreational value	Areas valued because they provide places for recreational activities
Spiritual value	Areas valued because they are sacred, religious, and spiritually important
Historical heritage value	Areas valued because they are places and things of natural and human history
Therapeutic value	Areas valued because they make people feel better, physically and/or mentally
Cultural heritage value	Areas valued because people can continue to pass down wisdom, traditions, and a way of life

Adapted from Brown (2004) and Alessa et al. (2008)

historic heritage, therapeutic, and cultural heritage (Table 3). The scale of the map was 1:500,000 allowing resolution of many locations to 500 m. The selection of cultural services was based on interviews with government officials and experts familiar to Noto, and based on the work by Brown (2004) and Alessa et al. (2008). The questionnaires were delivered by mail or by hand to local government officials. Each respondent was asked to identify and mark the top four important places as a dot for all seven cultural services. All the responses, as points marked on maps, were digitized and geo-referenced with GIS to produce a density surface map for each of the cultural services. Previous studies suggest that the use of density functions is more appropriate spatial treatment for cultural service point data than a spatial interpolation method such as inverse distance weighting (IDW) (Alessa et al. 2008). Density functions are suitable for mapping a variable with discontinuous spatial coverage across the study side while a spatial interpolation method is suitable for mapping a variable with continuous spatial coverage. In this study, a kernel point-density surface with a search radius of 500 m was employed to produce a density surface map of cultural service, which is based on a quadratic kernel function that generates a circular area (kernel) with a smoothly curved surface over each dot (Alessa et al. 2008; Nahuelhual et al. 2014).

Results

Provisioning services: agricultural, forest, livestock, and fishery production

The statistics of nine agricultural products were collected from the prefectural government of Ishikawa, all of which are designated as key agricultural products by the Bureau

of Agriculture, Forestry and Fisheries, Ishikawa prefecture (Ishikawa Prefecture 2006), along with statistics on timber, fisheries, and livestock production.

Regional comparisons of the production volume of agricultural provisioning services between Noto and Kaga region demonstrated that Kaga region produces more rice and most of the vegetables with a few exceptions including pumpkin and potato (subtotal of Table 4). Simple regression analysis of municipal statistics revealed a strong correlation between paddy area and rice yield ($r = 0.954$, $p < 0.001$). An interesting finding is that Kaga shows a higher unit rice yield, 3.9 tons/hectare, than that of Noto, 2.9 tons/Ha although the total area of paddy field cultivated for rice planting is almost at the same level between Noto and Kaga. This is due to the topographical differences between two regions. Because Noto is predominantly hilly and mountainous, it is often difficult to enlarge paddy plots through farmland consolidation projects, making paddy cultivation inefficient. In contrast, most paddy fields in Kaga are located on coastal plains with mountains behind, which have enabled the expansion of paddy plots. Furthermore, paddy fields in Kaga have an abundance of water resources for large-scale and efficient rice cultivation.

In regard to vegetable production, dry-field areas were only moderately correlated with pumpkin ($r = 0.525$, $p < 0.005$) and potato ($r = 0.666$, $p < 0.001$) yield. Kaga shows larger yields of leaf vegetables, radish, and fruits, whereas Noto is characterized by a larger yield of potato and pumpkin. Such differences could be explained from two aspects: (1) abundance of water resources available, and (2) greater distance to densely populated areas (Fig. 2c) or large consumption markets of Kaga. The topographic conditions of Noto result in rivers with a smaller watershed and a shorter period of water retention (Ishikawa Prefecture 2007). Only 3 out of 12 dams in Ishikawa are located in Noto, which has an average catchment area of 11.3 km² with an average effective storage capacity of 2.8 million m³, whereas dams in Kaga have an average catchment area of 98.8 km² with an average effective storage capacity of 30.5 million m³ (Ishikawa Prefecture 2013). In Noto, if agricultural water is available, it has traditionally been prioritized for irrigating rice, resulting in a larger yield of vegetables that require less irrigation such as potato. In contrast, vegetable production of Kaga, where large consumption markets are located, is characterized by leaf vegetables and fruits, which often require appropriate irrigation and are unsuitable for long-range transportation to markets.

Although Noto produces less agricultural provisioning services compared with Kaga, most Noto municipalities show greater timber production, fish catches, aquaculture production, as well as livestock production (subtotal of Table 5). A moderate correlation was obtained at

Table 4 Farmland area and yields of agricultural provisioning services (year and unit of data are shown under each item)

Region	Municipality	Paddy area 2014 Ha	Rice yield 2012 tons/ year	Dry-field area 2014 Ha	Leaf vegetables		Fruit vegetables		Root vegetables		Fruit	
					Spinach 2006 tons/ year	Japanese mustard spinach 2004 tons/year	Pumpkin 2006 tons/ year	Watermelon 2006 tons/year	Radish 2004 tons/ year	Potato 2004 tons/ year	Grape 2006 tons/ year	Nashi pear 2006 tons/ year
Noto	Wajima	2,620	6,020	1,910	50	20	100	100	490	400	0	0
	Suzu	1,680	4,710	1,420	10	40	820	110	350	330	0	30
	Noto	1,980	4,480	1,800	10	10	290	100	350	340	0	0
	Anamizu	1,300	2,280	950	0	10	240	270	220	150	40	0
	Shika	2,610	8,560	1,040	20	20	250	2,080	610	350	0	0
	Nanao	3,740	10,800	1,110	40	60	140	210	660	560	0	10
	Nakanoto	1,680	5,920	230	10	10	40	80	250	190	0	0
	Hakui	2,290	9,300	380	10	10	30	3,160	1,660	170	30	0
	Hodatsushimizu	1,500	5,100	390	10	10	40	60	160	150	220	10
	Subtotal	19,400	57,170	9,230	160	190	1,950	6,170	4,750	2,640	290	50
Kaga	Kahoku	890	3,280	880	0	20	40	1,960	1,010	190	430	40
	Tsubata	1,760	6,210	770	0	230	50	200	170	90	10	160
	Uchinada	110	420	570	0	50	0	2,400	840	30	0	0
	Kanazawa	3,330	12,000	1,210	70	140	90	5,580	4,170	490	210	1,130
	Hakusan	4,790	19,200	210	40	460	40	190	940	230	10	610
	Nonoichi	330	1,260	0	0	0	10	10	40	30	0	0
	Kawakita	790	3,240	0	0	0	0	30	90	60	40	0
	Nomi	1,760	7,170	70	10	20	30	70	300	130	0	0
	Komatsu	3,880	15,500	1,000	140	250	60	140	1,220	360	70	10
	Kaga	3,340	13,400	590	40	10	260	330	990	410	230	1,880
Subtotal	20,980	81,680	5,300	300	1,180	580	10,910	9,770	2,020	1,000	3,830	

The data is provided from the office of statistics, Ishikawa prefecture

municipal level between the amount of timber produced and forest area ($r = 0.598$, $p < 0.001$). The fishing industry of Noto accounts for more than 90 % of the total prefectural production in terms of catch and production volume. Deeply indented coastlines of Noto have enabled an accumulation of aquaculture farms and fishing ports; 63 out of 69 fishing ports of Ishikawa are located in Noto. Also, sparsely populated areas of Noto (Fig. 2c) allow large-scale livestock farming practices, often regarded as a NIMBY in densely populated areas (Ilea 2008). Municipalities that raise a large number of livestock in Kaga, such as Uchinada, Hakusan, and Nomi, are all located at places a short distance from densely populated areas. Consequently, Noto can be characterized as the producer of multiple provisioning services, which covers not only agricultural production but also forest, fishery, and livestock production, and functions as an important service provider for surrounding areas.

Regulating services

The valuation of regulating services was conducted at three levels: regional, municipal and mesh, utilizing geographic information such as land use, vegetation, and precipitation with GIS. Formulas and local parameters used to estimate the biophysical volume of ecosystem services are shown in Tables 6 and 7. While regional and municipal level evaluation aimed to identify the relative abundance of regulating services between Noto and Kaga, and between all the municipalities of Ishikawa, mesh level evaluation aimed to explore spatial variation of regulating services at a finer scale, with a spatial resolution of 500 meters.

The regional analysis clarified that the abundance of regulating services is not very different between Noto and Kaga with respect to most of the regulating services. The differences in the biophysical quantity of regulating services between the two regions are within 4.4 to 21.3 %,

Table 5 Forest area and yields of forestry, fishery, and livestock provisioning services (year and unit of data are shown under each item)

Region	Municipality	Forest area	Timber production	Fish	Shell fish	Seaweed	Dairy cow	Beef cattle	Pig	Egg-laying hen
		2010 Ha	2013 m ³ /year	2011 tons/ year	2011 tons/ year	2011 tons/ year	207 Population	2007 Population	2007 Population	2007 Population
Noto	Wajima	32,730	31,100	13,700	380	120	0	80	0	0
	Suzu	18,660	9,100	9,950	120	30	490	610	0	0
	Noto	20,530	4,800	3,750	30	10	640	1,270	3,880	341,200
	Anamizu	13,490	9,000	530	170	10	200	500	0	367,100
	Shika	16,210	7,900	7,980	180	40	340	440	1,310	0
	Nanao	20,390	11,600	7,360	1,920	30	210	30	0	0
	Nakanoto	5,110	1,700	0	0	0	260	60	0	0
	Hakui	2,920	100	230	30	0	0	0	0	0
	Hodatsushimizu	7,150	300	90	20	0	0	0	3,480	158,900
	Subtotal	137,190	75,600	43,590	2,850	240	2,140	2,990	8,670	867,200
Kaga	Kahoku	2,500	1,400	610	10	0	0	0	2,490	0
	Tsubata	5,630	2,800	0	0	0	0	0	0	0
	Uchinada	240	0	170	10	0	1,640	90	0	0
	Kanazawa	27,330	9,800	750	0	0	0	0	0	0
	Hakusan	55,630	4,900	110	10	0	1,060	230	0	0
	Nonoichi	0	0	0	0	0	0	0	0	0
	Kawakita	0	0	0	0	0	0	0	0	0
	Nomi	3,560	1,400	10	0	0	0	0	2,990	0
	Komatsu	25,790	17,500	80	0	0	0	0	0	0
	Kaga	21,210	10,600	1,130	20	20	0	0	0	0
Subtotal	141,890	48,400	2,860	50	20	2,700	320	5,480	0	

The data is provided from the office of statistics, Ishikawa prefecture

except for water retention by forest ecosystem which varied by 42.0 % between the two regions (Table 8).

At the municipal level, significant differences in the volume of regulating services were observed between the municipalities (Table 8). Municipalities with large areas of paddy farmland such as Hakusan, Komatsu, Kaga, and Nanao, exhibited a large volume of flood mitigation, water retention, and soil erosion control services, originating from agricultural ecosystems. Most of these municipalities are located in Kaga. A similar trend was observed for forest regulating services. Hakusan, Kanazawa, Komatsu, and Wajima demonstrated a large volume of flood mitigation, water purification, water retention, soil erosion control, and CO₂ absorption services, originating from forest ecosystems. The paddy and forest areas are two major predictors to explain the total volume of regulating services. In fact, very strong correlations were found between paddy area and agricultural regulating services, and between forest area and forest regulating services at the municipal level, with the lowest correlation coefficient of 0.959 (Table 9), whereas no significant correlation was observed between dry-field area and agricultural regulating services. It should

be noted that the correlations between paddy area and forest regulating services, and between forest area and agricultural regulating services found in Table 9, are spurious due to the strong relationship between paddy and forest areas; municipalities with rural characteristics have both large paddy and forestland. To be more precise, the territorial scale of a municipality also influences on the abundance of regulating services; if the share of paddy and forest to a municipal territory is equal, a municipality with large territory naturally demonstrates larger amount of regulating services, which is a scale effect.

Mesh level evaluation of regulating services helps to avoid such scale effects. Three regulating services, flood regulation, water retention, and soil erosion control services originating from agricultural and forest ecosystems, were calculated and summed up by category at 500-m mesh. The result demonstrates significant differences in the distribution pattern of regulating services (Fig. 3). Most areas of Noto exhibit a medium to high volume of regulating services across the peninsula. In contrast, there are sharp differences in the volume of regulating services between coastal areas and inland areas of Kaga, which is

Table 6 Formulas employed to estimate agricultural and forest regulating services (parameters to be explained in Table 7 are shown in italics)

Regulating services arising from agricultural ecosystems	
Flood mitigation of paddy field [m ³]	$= (\text{Height of consolidated paddy levees [m]} - \text{depth of flooding water [m]}) \times \text{area of consolidated paddy fields [m}^2\text{]} + (\text{height of unconsolidated paddy levees [m]} - \text{depth of flooding water [m]}) \times \text{area of unconsolidated paddy fields [m}^2\text{]}$
Flood mitigation of dry crop field [m ³]	$= \text{Plow layer depth [m]} \times \text{effective porosity} \times \text{area of dry crop field [m}^2\text{]}$
Water retention by paddy field [m ³]	$= (\text{Subsurface percolation of consolidated paddy fields [m/day]} \times \text{irrigation period [day]} \times \text{area of consolidated paddy fields [m}^2\text{]} + \text{subsurface percolation of unconsolidated paddy fields [m/day]} \times \text{irrigation period [day]} \times \text{area of unconsolidated paddy fields [m}^2\text{]}) + \text{annual precipitation [mm]} / 1,000 \times \text{groundwater recharge rate} \times \text{gross area of paddy fields [m}^2\text{]} \times (365 - \text{irrigation period [day]}) / 365$
Water retention by dry crop field [m ³]	$= \text{Annual precipitation [mm]} / 1,000 \times \text{groundwater recharge rate} \times \text{area of dry crop field [m}^2\text{]}$
Soil erosion control [m ³ /year]	$= (\text{Soil erosion in abandoned farmland [m}^3\text{/Ha/year]} - \text{soil erosion in current situation [ton/Ha/year]}) \times \text{area of cultivated lands [m}^2\text{]} / 10,000$
Regulating services arising from forest ecosystems	
Soil erosion control [m ³ /year]	$= \text{Gross soil erosion in Japan [m}^3\text{/year]} \times \{(\text{forest area [m}^2\text{]} / 10,000) / \text{gross forest area in Japan [Ha]}\}$
Flood mitigation [m ³ /s]	$= \text{Forest area [m}^2\text{]} \times \text{probable maximum daily rainfalls with 100-year return period [mm/day]} \times (\text{rainwater runoff ratio in bare ground} - \text{rainwater runoff ratio in forest area}) \times 1 / 1,000 \times 1 / 86,400$
Water retention [m ³ /s]	$= \text{Forest area [m}^2\text{]} \times (\text{annual precipitation [mm/year]} \times \text{rainwater runoff ratio in bare ground} - \text{evapotranspiration [mm/year]}) \times 1 / (365 \times 24 \times 60 \times 60)$
CO ₂ absorption [ton/year]	$= (\text{Area of plantation forest [m}^2\text{]} / 10,000 \times \text{annual biomass growth of plantation forest [ton/Ha/year]} + \text{area of natural forest [m}^2\text{]} / 10,000 \times \text{annual biomass growth of natural forest [ton/Ha/year]}) \times \text{Carbon content ratio in wooden biomass} \times \text{molecular weight ratio of CO}_2\text{/Carbon}$

Adapted from Science Council of Japan (SCJ 2001) and National Research Institute of Agricultural Economics (1998)

especially true for flood regulation (Fig. 3a) and soil erosion control services (Fig. 3c). Such differences originate from the distributions of paddy and forest across the

regions, and also in the per unit area differences of regulating services between paddy and forest; forest tends to exhibit far larger volume per unit area of regulating services than other land use. Because Noto is predominantly hilly, mountainous, and covered by forest, most of the areas tend to demonstrate a medium to high volume of regulating services. The areas that have a relatively low level of regulating services are mostly urban areas with impervious surface and/or flat plains utilized for paddy cultivation. On the other hand, in Kaga, rich forest coverage can be observed in inland, hilly, and mountainous areas, whereas paddy field and built-up areas predominate on coastal flat plains, causing the significant differences in the distribution of regulating services. For the mesh level analysis, simple regression analysis revealed that there are moderate to strong positive correlations between forest area and the regulating services, whereas other land uses, including paddy field, showed weak to moderate negative correlations with the regulating services (Table 10). This implies that conversion from forest to other land use decreases regulating services.

Cultural services

Questionnaires were delivered to 8,000 residents of Noto and 1,864 residents of Kanazawa, of which 1,662 and 138 responded (response rate 21 and 7.5 %), respectively. A total of 18,606 dots were identified and ranked by respondents, which ranges from the maximum of 4,211 points for esthetic services to the minimum of 1,790 dots for cultural heritage services (Table 11). All the dots were digitized as point data and visualized as a kernel point-density surface with ArcGIS for each category of cultural services and for overall evaluation. A rank of dots evaluated by respondents was used as a weight, converting the rank information from 1 (most important) to 4 (fourth important), to weight 4 to 1, in generating a kernel point-density surface. The density surface has a spatial resolution of 500 m.

The perceived value of seven cultural services and the overall evaluation are shown in the maps in Fig. 4. These maps highlight four trends. First, the appreciation of cultural services spread throughout Noto as indicated by the map of overall evaluation (Fig. 4h), showing a concentration of areas with a high perceived value (colored in red) in several municipalities such as Wajima, Nanao, and Hakui. Second, locales of highly perceived value are centered around scenic sites, religious sites such as temples and shrines, cultural and historical heritages, and characteristic geography along the coast of Noto Peninsula, and their distributions differ from service to service. For example, the beautiful landscape of Shirayone sen-maida (rice terrace) (Qiu et al. 2013), Chirihama coast

Table 7 Parameters used to estimate regulating services

Parameters [unit]		References
Height of consolidated paddy levees	0.03 [m]	NRIAE (1998), SCJ (2001)
Height of unconsolidated paddy levees	0.174 [m]	NRIAE (1998), SCJ (2001)
Depth of flooding water	0.03 [m]	NRIAE (1998), SCJ (2001)
Plow layer depth	0.2 [m]	NRIAE (1998)
Effective porosity	0.187	NRIAE (1998)
Subsurface percolation of consolidated paddy fields	0.0179 [m/day]	NRIAE (1998), SCJ (2001)
Subsurface percolation of unconsolidated paddy fields	0.0141 [m/day]	NRIAE (1998), SCJ (2001)
Irrigation period	112 [day]	NRIAE (1998), SCJ (2001)
Groundwater recharge rate	0.28	NRIAE (1998), SCJ (2001)
Soil erosion in abandoned farmland	14.77 [ton/Ha/year]	NRIAE (1998), SCJ (2001)
Soil erosion in current situation	4.20 [ton/Ha/year]	NRIAE (1998), SCJ (2001)
Annual biomass growth of plantation forest	4.96 [ton/Ha/year]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Annual biomass growth of natural forest	1.94 [ton/Ha/year]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Carbon content ratio in wooden biomass	0.5	Greenhouse Gas Inventory Office of Japan (2014)
Molecular weight ratio of CO ₂ /Carbon	44/12	
Gross soil erosion in Japan	5,161 × 1,000,000 [m ³ /year]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Gross forest area in Japan	25,146 × 1,000 [Ha]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Landslide in non-forest	2.38 [Ha/km ²]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Landslide in forest	1.23 [Ha/km ²]	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Annual occurrence rate	1/3	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Probable maximum daily rainfalls with 100-year return period	191 [mm/day]	Japan Meteorological Agency (2014)
Rainwater runoff ratio in bare ground	0.9	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Rainwater runoff ratio in forest area	0.6	SCJ (2001), Joetsu City and Research Institute for Local Government (2013)
Evapotranspiration	710 [mm/year]	Sugito et al. (2013)

and Koiji kaigan coast were highly evaluated as locations providing esthetic service (Fig. 4a), whereas Ketataisha shrine, Issaki-hachiman shrine, and Soujiji temple were ranked highly for spiritual services (Fig. 4d). Distinctive landscapes of Noto were characterized by social and ecological features, which help to link a variety of cultural services with different locations. Third, although the distribution of the perceived value of cultural services was different from service to service, some places were commonly evaluated across different service categories. Notojima island of Nanao, for instance, demonstrated high value for its recreational and learning services. Wajima asaichi (morning bazaar) and Shirayone senmida (rice terrace) were also appreciated highly for their esthetic, recreational, and cultural heritage services. Thus,

each of the seven cultural services is not independent but is inter-related. The simple regression analysis between seven cultural services revealed that most cultural services have a weak positive relationship with more than two other cultural services (Table 12). The perceived value of learning services, for instance, had a weak correlation with esthetic ($r = 0.200$, $p < 0.001$), recreational ($r = 0.350$, $p < 0.001$), historical heritage ($r = 0.200$, $p < 0.001$), and cultural heritage services ($r = 0.248$, $p < 0.001$). Only therapeutic services had no or negligible correlation with the other cultural services. In addition, all the seven cultural services had no correlation with land use areas such as the area of paddy field, dry-field, forest and built-up areas, as well as with population distribution.

Table 8 Regulating services arising from agricultural and forest ecosystems for the municipalities of Ishikawa

Region	Municipality	Paddy field Ha	Dry-field Ha	Forest Ha	Agricultural ecosystems			Forest ecosystems			CO ₂ absorption tons-CO ₂ / year
					Flood mitigation 10 thousand m ³ /year	Water retention 10 thousand m ³ /year	Soil erosion control Thousand m ³ /year	Flood mitigation 10 thousand m ³ /year	Water retention 10 thousand m ³ /year	Soil erosion control 10 thousand m ³ /year	
Noto	Wajima	2,620	1,910	32,730	520	5,650	2,920	720,270	52,540	710	13,910
	Suzu	1,680	1,420	18,660	700	7,030	3,310	392,210	24,290	380	8,440
	Noto	1,980	1,800	20,530	540	5,580	2,790	428,120	28,910	420	9,270
	Anamizu	1,300	950	13,490	290	2,870	1,570	293,050	19,790	290	5,460
	Shika	2,610	1,040	16,210	710	6,670	3,280	361,630	21,380	350	7,850
	Nanao	3,740	1,110	20,390	1,070	10,200	4,580	460,450	31,160	450	10,730
	Nakanoto	1,680	230	5,110	530	4,840	2,130	112,560	6,870	110	2,840
	Hakui	2,290	380	2,920	760	7,050	3,140	66,450	4,060	70	1,390
	Hodatsushimizu	1,500	390	7,150	480	4,570	2,090	150,840	9,080	150	3,120
	Subtotal	19,400	9,230	137,190	5,600	54,460	25,810	2,985,580	198,080	2,930	63,010
Kaga	Kahoku	890	880	2,500	310	3,130	1,670	53,670	3,070	50	1,070
	Tsubata	1,760	770	5,630	560	5,440	2,740	130,990	7,500	130	2,410
	Uchinada	110	570	240	60	640	710	5,650	320	10	0
	Kanazawa	3,330	1,210	27,330	840	8,260	3,850	609,130	46,580	600	12,440
	Hakusan	4,790	210	55,630	1,490	14,720	6,090	1,251,710	126,640	1,230	24,730
	Nonoichi	330	0	0	90	990	460	0	0	0	0
	Kawakita	790	0	0	240	2,210	940	0	0	0	10
	Nomi	1,760	70	3,560	590	5,590	2,420	75,400	5,440	70	1,930
	Komatsu	3,880	1,000	25,790	1,390	13,120	5,990	542,170	37,080	530	12,920
	Kaga	3,340	590	21,210	1,140	11,960	4,910	446,920	54,710	440	10,380
Subtotal	20,980	5,300	141,890	6,710	66,060	29,780	3,115,640	281,340	3,060	65,890	

Table 9 Correlation coefficients (Pearson correlation) between land use areas and regulating services of municipalities ($n = 19$)

	Paddy area	Dry-field area	Forest area
Paddy area	1	0.248	0.842 ***
Dry-field area	0.248	1	0.405
Forest area	0.842 ***	0.405	1
Agricultural			
Flood mitigation	0.957 ***	0.126	0.754 ***
Water retention	0.959 ***	0.152	0.781 ***
Soil erosion control	0.963 ***	0.253	0.794 ***
Forest			
Flood mitigation	0.842 ***	0.389	0.999 ***
Water retention	0.815 ***	0.203	0.965 ***
Soil erosion control	0.842 ***	0.389	0.999 ***
CO ₂ absorption	0.877 ***	0.398	0.996 ***

Significant values are in bold

*** $p < 0.001$

Discussion

This study is the first attempt to value and map ecosystem services of the Noto Peninsula, one of GIAHS sites, to clarify the spatial variation of provisioning, regulating, and

cultural services. Both original data obtained through questionnaire surveys and secondary data from literatures, statistics and geographic information were utilized to measure and estimate ecosystem services. The results could serve as a scientific basis for conservation and development

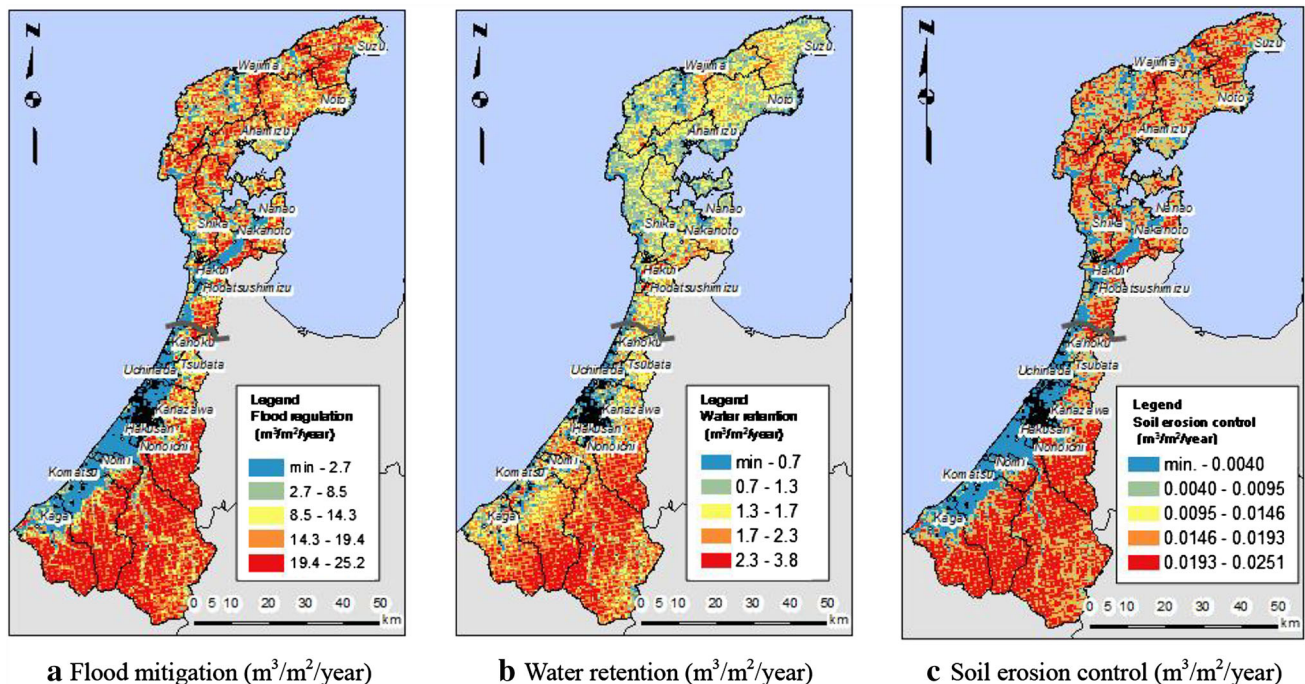


Fig. 3 Spatial variation of flood mitigation, water retention, and soil erosion control ($\text{m}^3/\text{m}^2/\text{year}$) across Ishikawa prefecture. Gray thick lines between Houdatsushimizu and Kahoku in each map represent a boundary between the Noto and Kaga regions

planning for the Noto Peninsula, for instance, by providing information necessary to define high priority areas for conservation (Raymond et al. 2009), and to improve our understanding about the potential trade-offs to ecosystem services originating from development practices (Shoyama and Yamagata 2014).

Geography and natural resources are important determinants of provisioning and regulating services

Our analysis identified that the types and amounts of agricultural provisioning services are largely constrained by geographical conditions such as topography and distance from large markets. The topography limits the available water resources and agricultural labor productivity, while the distance from large markets combines with the topography factor to limit the type of economically viable crops that can be grown in the Noto Peninsula. Although relatively unfavorable for farming, rich natural resources and intended coastlines help the Noto Peninsula to take a large share of the forest and fishery sectors. In addition, remoteness from large consumption markets seems to allow locating a relatively large livestock industry in this area, which is too often unwanted in densely populated areas. Valuation of multiple provisioning services across different sectors suggests that all of these services could contribute to support the livelihood of local people and the sustainable use and management of natural

resources of the Noto Peninsula. Over the years, these services have shaped intricate linkages between people and nature as social–ecological production landscapes. Such aspects, or how local geography and natural resources support and/or constrain available provisioning services, were not effectively addressed in the past assessment effort of JSSA as it focused primarily on much larger spatial scales for exploring conditions and trends of ecosystem services (Duraiappah et al. 2012).

Statistics provided only a limited understanding of the detailed diversity of Noto’s provisioning services. Although it has been reported that there are 11 classes of agricultural and non-timber forest products with 705 varieties produced or harvested in Noto (FAO 2011), our statistical analysis could cover only part of such diversity. Statistics kept by the national and/or local governments focus mainly on key product items that have a major role in economies, and thus are uninterested in keeping records of the yield of minor products that have minor economic contribution to the local economy. For example, the “rice” consists of several items such as ordinary rice or non-glutinous rice, glutinous rice, rice for sake brewing, and ancient rice, each of which has its own varieties with different characters such as tastes and textures, and they play important roles in shaping and maintaining rice-related biocultural diversity (Cocks 2006). All of these varieties, however, are aggregated as “rice” in the survey, making it impossible to clarify the yield of each variety. A local

Table 10 Correlation coefficients (Pearson's correlation) between land use areas and regulating services at mesh level ($n = 17,188$)

	Paddy area	Dry-field area	Forest area	Built-up area	Traffic area	Other urban area
Paddy field area	1	-0.002	-0.564 ^{***}	0.187 ^{***}	0.101 ^{***}	0.029 ^{***}
Dry-field area		1	-0.215 ^{***}	0.043 ^{***}	0.038 ^{***}	0.005
Forest area			1	-0.501 ^{***}	-0.224 ^{***}	-0.246 ^{***}
Built-up area				1	0.189 ^{***}	0.209 ^{***}
Traffic area					1	0.076 ^{***}
Other urban area	0.029 ^{***}	0.005	-0.246 ^{***}	0.209 ^{***}	0.076 ^{***}	1
Flood regulation	-0.549 ^{***}	-0.207 ^{***}	0.856 ^{***}	-0.480 ^{***}	-0.203 ^{***}	-0.201 ^{***}
Water retention	-0.005	-0.182 ^{***}	0.548 ^{***}	-0.401 ^{***}	-0.175 ^{***}	-0.196 ^{***}
Soil erosion control	-0.536 ^{***}	-0.202 ^{***}	0.854 ^{***}	-0.482 ^{***}	-0.204 ^{***}	-0.203 ^{***}

Significant values are in bold
^{***} $p < 0.001$

Table 11 Number of places evaluated in the questionnaire survey

	Number of places evaluated
Esthetic	4,211
Educational	1,958
Recreational	2,913
Spiritual	3,101
Historical	2,510
Therapeutic	2,123
Cultural	1,790
Total	18,606

community might be an appropriate scale of assessment to explore the diversity of provisioning services and their contributions to biocultural diversity, which is one area of further research.

Regional and municipal level analysis clarified that a municipality of large forest and paddy areas demonstrated a higher volume of regulating service, which is a scale effect. One should be careful about comparing ecosystem services among spatial units of different surface areas (Su et al. 2011) because differences of surface area are likely to affect the total volume of and/or value of ecosystem services produced in regions. To explore spatial variation of regulating services without the scale effect, the mesh level analysis was performed in this study. This identified stark differences in the distribution patterns of flood mitigation, soil erosion control, and water retention services between Noto and Kaga regions; although two regions showed a similar level of regulating services in terms of the biophysical volume. Here, geographical conditions also played an important role in the provision of regulating services. Type of land use and cover were differentiated between spatial distribution of regulating services. To be more precise, forest has a far larger volume per unit area of regulating services than other land use, and thus its location worked as an important determinant in causing spatial variation of regulating services. Thus, conversion from forest to other land use for the sake of land

reclamation and residential development could decrease the total volume of regulating services. This is an important finding for policy makers to take into consideration in conservation and development planning.

One significant characteristics of the Noto Peninsula is the close co-location of human habitats and areas of medium to high volume of regulating service because the peninsula is predominantly hilly and mountainous with rich forest coverage, interspersed with other land use including residential areas. In contrast, in Kaga, areas with medium to high volume of regulating services are mostly located in inland mountainous areas, which are distant from densely populated areas found on the coastal plains. This finding carries the implication for policy makers that forest management would have a critical role as a means of disaster management in the Noto Peninsula (Hanewinkel et al. 2010), because the decrease in regulating services such as flood mitigation and soil erosion control resulted from forest conversions are likely to impair safe living environments.

In addition, differences in the distribution patterns of regulating services might also influence how people perceive the benefit of regulating services, along with other factors identified in previous studies, such as people's affiliation and knowledge about nature (Hein et al. 2006; Lamarque et al. 2011). People could underestimate the benefit of regulating services when service providing areas and service benefiting areas are located at distant places (Fisher et al. 2009). Building peoples' proper understanding about the benefits of ecosystem services is of great importance for integrating the ecosystem services concept into development practices (Daily et al. 2009).

Traditional and cultural constructions as an anchor to link cultural service to specific locale

The areas with moderate to high perceived value of cultural services were often centered on and around well-known natural and artificial landscape components such as scenic

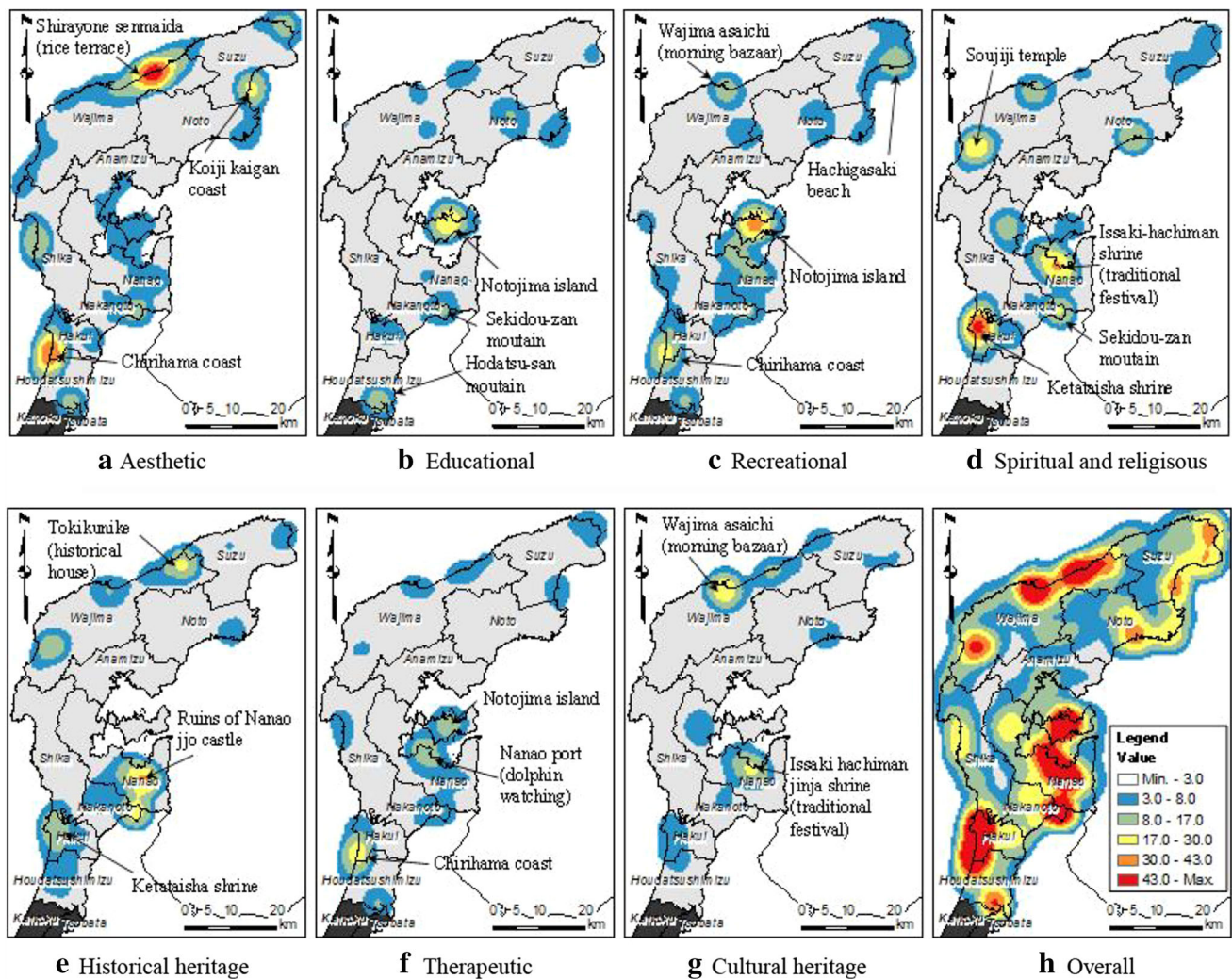


Fig. 4 Perceived value of cultural services (points/Ha)

Table 12 Pairwise correlation coefficients (Pearson’s correlation) ($n = 17,188$)

	Esthetic	Educational	Recreational	Spiritual	Historical heritage	Therapeutic	Cultural heritage
Esthetic	1	0.200***	0.221***	0.119	0.176	0.109	0.176
Educational		1	0.350***	0.160	0.200***	0.191	0.248***
Recreational			1	0.168	0.173	0.145	0.209***
Spiritual				1	0.184	0.107	0.283***
Historical heritage					1	0.148	0.242***
Therapeutic						1	0.167
Cultural heritage							1

Significant values are in bold

*** $p < 0.001$

sites and religious sites along the coast. This finding differs from those identified in the work by Alessa et al. (2008) on Kenai Peninsula of Alaska. Our finding indicates that intangible services such as recreational and historical heritage services tend to exhibit a lower perceived value with

little geographical concentration on specific areas due to the lack of physical anchors that link specific services to locales. Presumably, such differences between the two studies might arise from the different characteristics of the case study areas such as geographical scale, population

distribution, land use, and the history of human habitation. Various traditional and cultural constructions such as temples and shrines have been built and managed over the long history of the Noto Peninsula, which have helped people to associate both intangible and tangible cultural services to specific places along with natural landscape components such as mountains and coasts. The perceived value of most of the cultural services is weakly inter-related with each other at the mesh level but is not related with land use factors, which differs from the analytical results for the provisioning and regulating services. Previous studies suggest that there are functional relationships between the levels of ecosystem services provision and land use, and, in general, cultural services are high in pristine to lightly used landscapes (de Groot et al. 2010). Such relationships between cultural services and land use, however, were not observed in this study presumably because this study relied on subjective evaluation of questionnaire respondents for the valuation of cultural services. The analysis on the relationship between cultural services and land use and other ecosystem service categories remain an issue for further study.

Policy makers could utilize our maps of perceived cultural services to identify areas with high values for their conservation and sustainable use in landscape planning (Raymond et al. 2009). However, it should be also noted that our maps merely represent the subjective valuation by respondents, and do not assess scientific or historical values of specific locales. Locales with a low profile might be undervalued or might not be valued by respondents, even if the location is historically or scientifically important. In this regard, the maps could also be useful to explore locales that need special care to fill the gap between peoples' understanding or subjective valuation, and scientific or historical value for its sustainable management.

Conclusions

This study extends our understanding about types, abundance and spatial variation of ecosystem services arising from the social–ecological landscapes of Noto Peninsula, Japan, through mapping and evaluation of provisioning, regulating, and cultural services. First, the hilly and mountainous geography of the Noto Peninsula, and its remoteness from large consumption markets, constrain the types and abundance of agricultural provisioning services by limiting water resources, labor productivity, choice of economically viable crops. Although their rich forests, and marine and coastal resources provide various economic opportunities for forestry-, fishery- and livestock-related provisioning services. Second, geographical conditions such as land use and cover type also played an important

role in differentiating spatial variation of regulating services. Stark differences in spatial distribution of regulating services between Noto and Kaga regions, which suggest that landscape management would play a more important role in the Noto Peninsula than the Kaga region for maintaining safe living environments because most of the area demonstrates medium to high volume of regulating services in close proximity to human habitation. Finally, unlike provisioning and regulating services, natural and artificial landscape components, including traditional and cultural constructions such as shrines and temples work as an anchor to help people appreciate intangible and tangible cultural services, linking different services to specific locales across the Noto Peninsula.

Acknowledgments The authors are grateful to government officials of Ishikawa prefecture and Suzu city who devoted their time to the interview in the early stage of this study. This research was supported by the Environment Research and Technology Development Fund (1-1303) of the Ministry of the Environment, Japan, and by JSPS KAKENHI Grant Number 24780230.

References

- Aizaki H, Sato K, Osari H (2006) Contingent valuation approach in measuring the multifunctionality of agriculture and rural areas in Japan. *Paddy Water Environ* 4:217–222. doi:[10.1007/s10333-006-0052-8](https://doi.org/10.1007/s10333-006-0052-8)
- Alessa L (Naia), Kliskey A (Anaru), Brown G (2008) Social–ecological hotspots mapping: a spatial approach for identifying coupled social–ecological space. *Landsc Urban Plan* 85:27–39. doi:[10.1016/j.landurbplan.2007.09.007](https://doi.org/10.1016/j.landurbplan.2007.09.007)
- Barrena J, Nahuelhual L, Báez A et al (2014) Valuing cultural ecosystem services: agricultural heritage in Chiloé island, southern Chile. *Ecosyst Serv* 7:66–75. doi:[10.1016/j.ecoser.2013.12.005](https://doi.org/10.1016/j.ecoser.2013.12.005)
- Brown G (2004) Mapping spatial attributes in survey research for natural resource management: methods and applications. *Soc Nat Resour* 18:17–39. doi:[10.1080/08941920590881853](https://doi.org/10.1080/08941920590881853)
- Chang K, Ying Y (2005) External benefits of preserving agricultural land: Taiwan's rice fields. *Soc Sci J* 42:285–293. doi:[10.1016/j.soscij.2005.03.008](https://doi.org/10.1016/j.soscij.2005.03.008)
- Cocks M (2006) Biocultural diversity: moving beyond the realm of “indigenous” and “local” people. *Hum Ecol* 34:185–200. doi:[10.1007/s10745-006-9013-5](https://doi.org/10.1007/s10745-006-9013-5)
- Daily GC, Polasky S, Goldstein J et al (2009) Ecosystem services in decision making: time to deliver. *Front Ecol Environ* 7:21–28. doi:[10.1890/080025](https://doi.org/10.1890/080025)
- de Groot RS, Alkemade R, Braat L et al (2010) Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. *Ecol Complex* 7:260–272. doi:[10.1016/j.ecocom.2009.10.006](https://doi.org/10.1016/j.ecocom.2009.10.006)
- Duraiappah AK, Koji N, Kazuhiko T et al (2012) Satoyama–satoumi ecosystems and human well-being: socio-ecological production landscapes of Japan. United Nations University Press, Tokyo
- Egoh B, Rouget M, Reyers B et al (2007) Integrating ecosystem services into conservation assessments: a review. *Ecol Econ* 63:714–721. doi:[10.1016/j.ecolecon.2007.04.007](https://doi.org/10.1016/j.ecolecon.2007.04.007)
- FAO (2011) Proposal of Noto's Satoyama and Satoumi, pp 1–74. http://www.fao.org/fileadmin/templates/giahs_assets/Sites_annexes/Noto_Proposal.pdf

- Fisher B, Turner RK, Morling P (2009) Defining and classifying ecosystem services for decision making. *Ecol Econ* 68:643–653. doi:10.1016/j.ecolecon.2008.09.014
- Greenhouse Gas Inventory Office of Japan (2014) National Greenhouse Gas Inventory Report of Japan, vol 674. <http://www-gio.nies.go.jp/aboutghg/nir/2014/NIR-JPN-2014-v3.0.pdf>
- Gu H, Subramanian SM (2014) Drivers of change in socio-ecological production landscapes: implications for better management. *Ecol Soc* 19(1):41. doi:10.5751/ES-06283-190141
- Hanewinkel M, Hummel S, Albrecht A (2010) Assessing natural hazards in forestry for risk management: a review. *Eur J For Res* 130:329–351. doi:10.1007/s10342-010-0392-1
- Harrop SR (2007) Traditional agricultural landscapes as protected areas in international law and policy. *Agric Ecosyst Environ* 121:296–307. doi:10.1016/j.agee.2006.12.020
- Hein L, van Koppen K, de Groot RS, van Ierland EC (2006) Spatial scales, stakeholders and the valuation of ecosystem services. *Ecol Econ* 57:209–228. doi:10.1016/j.ecolecon.2005.04.005
- Hernández-Morcillo M, Plieninger T, Bieling C (2013) An empirical review of cultural ecosystem service indicators. *Ecol Indic* 29:434–444. doi:10.1016/j.ecolind.2013.01.013
- Huang CC, Tsai MH, Lin WT et al (2006) Multifunctionality of paddy fields in Taiwan. *Paddy Water Environ* 4:199–204. doi:10.1007/s10333-006-0049-3
- Ilea RC (2008) Intensive livestock farming: global trends, increased environmental concerns, and ethical solutions. *J Agric Environ Ethics* 22:153–167. doi:10.1007/s10806-008-9136-3
- Indrawan M, Yabe M, Nomura H, Harrison R (2014) Deconstructing satoyama—the socio-ecological landscape in Japan. *Ecol Eng* 64:77–84. doi:10.1016/j.ecoleng.2013.12.038
- Ishikawa Prefecture (2006) Vision of food and agriculture in Ishikawa, Ishikawa prefecture (in Japanese). <http://www.pref.ishikawa.lg.jp/nousei/vision/documents/all.pdf>
- Ishikawa Prefecture (2007) Development plan of the Noto peninsula region (in Japanese). <https://www.pref.ishikawa.lg.jp/shinkou/hantou/documents/keikaku.pdf>
- Ishikawa Prefecture (2013) Dams of Ishikawa (in Japanese). <http://www.pref.ishikawa.lg.jp/kasen/ishikawa-dam/dams/index.html>. Accessed 1 Oct 2014
- Japan Meteorological Agency (2014) Risk map of extreme weather (in Japanese). http://www.data.jma.go.jp/cpdinfo/riskmap/qt_table.html
- Joetsu City and Research Institute for Local Government (2013) Development policy for hilly and mountainous area (in Japanese). http://www.rilg.or.jp/004/h24/h24_02.pdf
- Johnson KA, Polasky S, Nelson E, Pennington D (2012) Uncertainty in ecosystem services valuation and implications for assessing land use tradeoffs: an agricultural case study in the Minnesota River Basin. *Ecol Econ* 79:71–79. doi:10.1016/j.ecolecon.2012.04.020
- Koohafkan P, Jane M (2011) Conservation and adaptive management of globally important agricultural heritage systems (GIAHS). *J Resour Ecol* 2:22–28. doi:10.3969/j.issn.1674-764x.2011.01.004
- Lamarque P, Tappeiner U, Turner C et al (2011) Stakeholder perceptions of grassland ecosystem services in relation to knowledge on soil fertility and biodiversity. *Reg Environ Change* 11:791–804. doi:10.1007/s10113-011-0214-0
- Layke C, Mapendembe A, Brown C et al (2012) Indicators from the global and sub-global Millennium Ecosystem Assessments: an analysis and next steps. *Ecol Indic* 17:77–87. doi:10.1016/j.ecolind.2011.04.025
- MA (2005) Ecosystems and human well-being: general synthesis. Island Press, Washington
- Matsuno Y, Nakamura K, Masumoto T et al (2006) Prospects for multifunctionality of paddy rice cultivation in Japan and other countries in monsoon Asia. *Paddy Water Environ* 4:189–197. doi:10.1007/s10333-006-0048-4
- Milcu AI, Hanspach J, Abson D, Fischer J (2013) Cultural ecosystem services: a literature review and prospects for future research. *Ecol Soc*. doi:10.5751/ES-05790-180344
- Morri E, Pruscini F, Scolozzi R, Santolini R (2014) A forest ecosystem services evaluation at the river basin scale: supply and demand between coastal areas and upstream lands (Italy). *Ecol Indic* 37:210–219. doi:10.1016/j.ecolind.2013.08.016
- Nahuelhual L, Carmona A, Laterra P et al (2014) A mapping approach to assess intangible cultural ecosystem services: the case of agriculture heritage in Southern Chile. *Ecol Indic* 40:90–101. doi:10.1016/j.ecolind.2014.01.005
- Naidoo R, Balmford A, Costanza R et al (2008) Global mapping of ecosystem services and conservation priorities. *Proc Natl Acad Sci USA* 105:9495–9500. doi:10.1073/pnas.0707823105
- Natuhara Y (2013) Ecosystem services by paddy fields as substitutes of natural wetlands in Japan. *Ecol Eng* 56:97–106. doi:10.1016/j.ecoleng.2012.04.026
- Ninan KN, Inoue M (2013) Valuing forest ecosystem services: Case study of a forest reserve in Japan. *Ecosyst Serv* 5:78–87. doi:10.1016/j.ecoser.2013.02.006
- NRIAE (1998) Calculation of public functions of agriculture and rural areas with replacement cost method. *Q J Agric Econ* 52:113–138
- Ostrom E (2009) A general framework for analyzing sustainability of social-ecological systems. *Science* 325:419–422. doi:10.1126/science.1172133
- Power AG (2010) Ecosystem services and agriculture: tradeoffs and synergies. *Philos Trans R Soc Lond B Biol Sci* 365:2959–2971. doi:10.1098/rstb.2010.0143
- Qiu J, Turner MG (2013) Spatial interactions among ecosystem services in an urbanizing agricultural watershed. *Proc Natl Acad Sci USA* 110:12149–12154. doi:10.1073/pnas.1310539110
- Qiu Z, Chen B, Takemoto K (2013) Conservation of terraced paddy fields engaged with multiple stakeholders: the case of the Noto GIAHS site in Japan. *Paddy Water Environ* 12:275–283. doi:10.1007/s10333-013-0387-x
- Raudsepp-Hearne C, Peterson GD, Bennett EM (2010) Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proc Natl Acad Sci USA* 107:5242–5247. doi:10.1073/pnas.0907284107
- Raymond CM, Bryan BA, MacDonald DH et al (2009) Mapping community values for natural capital and ecosystem services. *Ecol Econ* 68:1301–1315. doi:10.1016/j.ecolecon.2008.12.006
- SCJ (2001) Evaluating the multi-functionalities of agriculture and forest related to the global environment and the society: report in response to an inquiry from the Ministry of Agriculture, Forestry and Fisheries (in Japanese). <http://www.scj.go.jp/ja/info/kohyo/pdf/shimon-18-1.pdf>
- Shoyama K, Yamagata Y (2014) Predicting land-use change for biodiversity conservation and climate-change mitigation and its effect on ecosystem services in a watershed in Japan. *Ecosyst Serv* 8:25–34. doi:10.1016/j.ecoser.2014.02.004
- Su C, Fu B, Wei Y et al (2011) Ecosystem management based on ecosystem services and human activities: a case study in the Yanhe watershed. *Sustain Sci* 7:17–32. doi:10.1007/s11625-011-0145-1
- Sugito H, Nishimura T, Kato C et al (2013) Analysis of runoff in the Tedorigawa basin using mesh data of gamsDB in Japanese. *Proc Jpn Soc Irrig Drain Rural Eng* (in Japanese), pp 72–73
- Tallis H, Polasky S (2009) Mapping and valuing ecosystem services as an approach for conservation and natural-resource management. *Ann N Y Acad Sci* 1162:265–283. doi:10.1111/j.1749-6632.2009.04152.x
- Tallis H, Kareiva P, Marvier M et al (2008) An ecosystem services framework to support both practical conservation and economic development. *Proc Natl Acad Sci USA* 105:9457–9464

- Van Riper CJ, Kyle GT, Sutton SG et al (2012) Mapping outdoor recreationists' perceived social values for ecosystem services at Hinchinbrook Island National Park, Australia. *Appl Geogr* 35:164–173. doi:[10.1016/j.apgeog.2012.06.008](https://doi.org/10.1016/j.apgeog.2012.06.008)
- Xie J, Hu L, Tang J et al (2011) Ecological mechanisms underlying the sustainability of the agricultural heritage rice-fish coculture system. *Proc Natl Acad Sci USA* 108:E1381–E1387. doi:[10.1073/pnas.1111043108](https://doi.org/10.1073/pnas.1111043108)
- Yoshida K, Hayashi K (2012) The biodiversity observation network in the Asia-Pacific Region. In: Nakano S, Yahara T, Nakashizuka T (eds) *Biodiversity observation network in the Asia-Pacific Region*. Springer Japan, Tokyo, pp 27–35