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ORIGINAL RESEARCH

Land use changes in globally important cultural forests. The case of two traditionally managed forests for non-wood forest products (NWFPs) in China and Japan

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Abstract

Non-Wood Forest Products (NWFPs) still have a key role for the economy of many rural areas, for their sustainable development and for preserving traditional culture, landscape and biodiversity. Two sites inscribed in the Globally Important Agricultural Heritage Systems (GIAHS) Programme of the Food and Agriculture Organization (FAO) are based on traditional forest management devoted to shitake production: the Kunisaki Peninsula System (Japan) and the Qingyuan Forest-Mushroom Co-culture System (China). This study investigated the landscape structure of the two sites, assessing the land use changes in the last 10 years, and identifying the main drivers responsible of changes, through GIS-based spatial analyses of 2008 and 2019 land use maps. An accuracy assessment of the original databases has also been performed to validate the research findings. Results demonstrated that the maintenance of the traditional forest management has effectively contributed to the preservation of two different but both traditional landscape structures, but the methodology also allowed to identify some external pressures. In the Kunisaki peninsula the abandonment of agricultural surfaces (-4.3%) and consequent spread of grasslands (+63%) and forests (+1.3%) mainly affects areas at lower altitudes; in Qingyuan County deforestation (+280 ha/year), expansion of new cultivations (+250 ha/year) and urban sprawl (+67%), represent the main changes. Traditional forest practices represent effective examples of sustainable forest management, capable of providing high-quality NWFPs and ecosystem services to local communities, contributing to the preservation of local natural resources, of cultural heritage, and of biodiversity at the landscape scale.

Keywords Cultural forests · Non-wood forest products · NWFP · Land use change · Sustainable forest management · GIAHS · Agricultural heritage

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Introduction

Non-wood forest products (NWFPs) are defined by the Food and Agriculture Organization of the United Nations (FAO) as "goods of biological origin other than wood derived from forests and other wooded land and trees outside forests" (FAO 1999) or as "goods derived from forests and other wooded land that are tangible and physical objects of biological origin other than wood" (Muir et al. 2020). According to the level of human management of the forest environment, NWFPs can be classified in three types: Wild forest products, Semi-wild forest products, or Managed forest products. NWFPs include a wide range of different products: wild fruits, nuts, wild vegetables or tubers, mushrooms, edible animals and insects, honey, fodder, construction materials, rubber and resin, cork. NWFPs contribute to different classes of ecosystem services, such as providing human nutrients and renewable materials, providing cultural services (maintenance of traditions and local identity), or creating jobs and income opportunities that can be particularly relevant in marginal rural areas (Weiss et al. 2020; Leakey et al. 2021). According to the FAO, at least 3.5 billion people around the world commonly use NWFPs (FAO 2022), while in Europe the value of wild-collected forest products (including formally and informally marketed and self-consumed products) is estimated at 23.3 billion of euros per year (Lovrić et al. 2020). Therefore, these products can play pivotal roles in forestry and rural development, despite the lack of policies or financial support specifically dedicated to NWFPs (Sacchelli et al. 2021). Asia is home to many traditional agroforestry systems based on NWFPs that were already exported more than 10 years ago, highlighting their economic relevance (Hansda 2009).

Most of NWFPs are strictly connected to traditional management of cultural forests. In some cases, they can be considered as a byproduct of a forest management mainly devoted to timber or firewood production, while in other cases the forest is specifically managed with the main purpose of obtaining a NWFP. These traditional forms of cultural forest management are not only important for NWFPs or for the intrinsic cultural value and for strengthening the cultural identity of rural communities, but are also crucial for the preservation of a cultural landscape and of the associated agrobiodiversity, and for providing a wide range of ecosystem services (Piras et al. 2022). It is in fact widely recognized that traditional and sustainable agro-silvo-pastoral practices can have positive effects on the preservation and restoration of habitats, on the protection of watersheds, on the preservation and improvement of soil health and water quality (Howden et al. 2007), and also as examples of climate change adaptation and/or mitigation.

Based on the idea of preserving traditional agro-silvo-pastoral systems developed through the centuries with their landscapes, agro-biodiversity, traditional knowledge and associated culture, in 2002, the FAO established the Globally Important Agricultural Heritage Systems (GIAHS) Programme (Koohafkan and Altieri 2011; Ramakrishnan 2004). These systems still provide many ecosystem services to the local communities, as well as food and livelihood security for millions of small-scale farmers while contributing to climate change mitigation, applying the dynamic conservation principles. In addition, the GIAHS Programme intends to promote a rural development model alternative to the one based on maximizing productivities and yields that turned out to be economically and environmentally unsustainable in many rural areas, as well as ineffective in solving the problem of hunger at global level. Intensive agriculture is in fact often based on fossil fuels, chemicals and fertilizers, with negative impacts on the environment, on soils, on climate change and also on public health (Erb et al. 2008; Kopittke et al. 2019; Li et al. 2020). The agro-silvo-pastoral model promoted by the GIAHS Programme, is instead based on traditional agricultural and silvicultural practices, that supported local communities for centuries, and that nowadays is capable of producing high-quality food products. As for July 2023, 74 systems in 24 countries are inscribed in the GIAHS programme. Many of these systems are based on traditional forest or agroforestry practices, and NWFPs can represent an economic and cultural resource, even if only in few cases NWFPs are properly valorized in national or international markets, while in most cases they are only consumed locally (Santoro et al. 2020). These forests, that are still managed according to traditional and sustainable practices, can be considered cultural forests and are still able to provide different ecosystem services to the local communities (Piras et al. 2022).

Among the sites inscribed in the FAO GIAHS Programme, two of them are characterized by a specific forest management dedicated to shitake mushroom (*Lentinula edodes*) production: the Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System (Japan, inscribed in 2013) and the Qingyuan Forest-Mushroom Co-culture System in Zhejiang Province (China, inscribed in 2022). Shitake is a white rot fungus that is considered one of the most efficient lignin degraders in nature (Oki et al. 1981) and one of the most commonly consumed and cultivated mushroom species in the world, and probably one of the earliest species to be cultivated (Gu et al. 2019). Shiitake cultivation began centuries ago when wild shitake growing on fallen trees during the spring and autumn were collected in the forest (Ito 1978; Royse and Schisler 1980; Singer 1961). It was later discovered that the trunk pieces found in the forest bearing shiitake could be moved into courtyards and continued to produce shitake for several years. Therefore, traditional shitake production started to be carried out on oak logs stored on specific sites with adequate canopy cover (Ito 1978), considering that optimum conditions are temperatures between 15° and 28 °C and a relative humidity of 80–85% (Leatham 1981). In addition, the history of these two sites is strictly connected, as Chinese growers introduced shitake cultivation techniques to Japanese farmers, who named the mushroom and were later responsible for its spread eastward (Royse 2009). Shitake, a common ingredient of many Asian cuisines and also a medicinal and nutraceutical source (Atila 2019), rapidly resulted in an important agricultural product both for Japan and China. In Japan, in 1978 shitake industry already employed 188,000 people and generated $1.1 billion in retail sales, while dried shitake was Japan's major agricultural export (Leatham 1981). In the same year the production of cultivated edible mushrooms in China accounted for only 5.7% of total world production, while in 2002 it reached about 70% of the total world output, becoming the largest mushroom producer, consumer, and exporter in the world (Chang 2006). According to Zhang et al. (2014) in 2014 about 25 million farmers in China were engaged in the collection, cultivation, processing or marketing of mushrooms.

In both of the aforementioned GIAHS sites, traditional forest management has been developed through the centuries not to maximize or to optimize timber or firewood production, but for allowing the production of shitake mushrooms, that represented a crucial economic resource for the local rural communities. In these sites it is evident that NWFPs have the potentiality to represent a key economic resource for rural communities living in marginal areas, and that their production can strongly be linked to the sustainable management of forest resources. In marginal rural areas, where agriculture or silviculture are not economically sustainable, NWFPs can play a crucial role for the sustainable development based on circular bioeconomy, representing an additional and differentiated source of income for farmers, at the same time preserving traditional landscapes and the associated biodiversity and agrobiodiversity, as well as traditional knowledge and cultural values. Despite the importance of NWFPs for the local economies and for preserving the traditional forest landscapes, external pressures are currently threatening the two sites (The People's Government of Qingyuan County, Zhejiang Province 2022; GIAHS Promotion Association of Kunisaki Peninsula Usa Area (2013). Even well-preserved cultural forests related to NWFPs, or agroforestry and agricultural heritage systems, in fact, are subjected to internal and external pressures, often caused by socio-economic changes, that can jeopardize the overall level of integrity. Therefore, it is crucial to provide reliable data for future monitoring of land use changes, as well as applying innovative approaches for real-time control of the environmental conditions and to develop efficient systems of management and governance based on the sustainable development principles (Martins et al. 2022; Sugimoto et al. 2021).The main aim of this paper is to compare these two different forest systems, both dedicated to traditional shitake production. In particular, the research aims at:

i. characterizing the sites in terms of land uses and assessing land use changes in the last 10 years;
ii. identify the main pressures and drivers responsible of land use changes.

Results can help local stakeholders and planners to support and address sustainable forest management and to develop conservation strategies. In addition, the findings of this research could also be of interest of the FAO GIAHS secretariat to check the effectiveness of the inclusion in this FAO Programme regarding landscape transformations. This study can also contribute to identify knowledge gap in relation to NWFPs and sustainable forest management from a landscape and land use change perspective.

Materials and methods

The study areas

The study areas correspond to two different GIAHS sites, one in Japan and one in China (Fig. 1), both characterized by a Humid subtropical climate (*Cfa*) according to the Köppen-Geiger climate classification (Kottek et al. 2006).

The Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System, is located in Oita Prefecture (Japan) and extends for 131,687 hectares. The Kunisaki Peninsula is characterized by mountain ridges extending radially from the central lava dome with altitudes ranging from the sea level to 1062 m a.s.l. The site is home to about 140,000 people, of which about 10,000 are engaged in agriculture, forestry and fisheries. Kunisaki GIAHS site is characterized by interconnected forests and farming plots interspersed among irrigation ponds, a system that has enabled local farmers to tolerate periodical droughts for centuries (Hayashi 2014; Vafadari 2013). Shitake cultivation was introduced in Kunisaki peninsula in the 19th century and started to rapidly spread as this activity resulted in improved incomes compared to rice. Therefore, the region became the main production area for log wood cultivated shitake in the country, mainly based on Sawtooth Oak (*Quercus acutissima*) for-

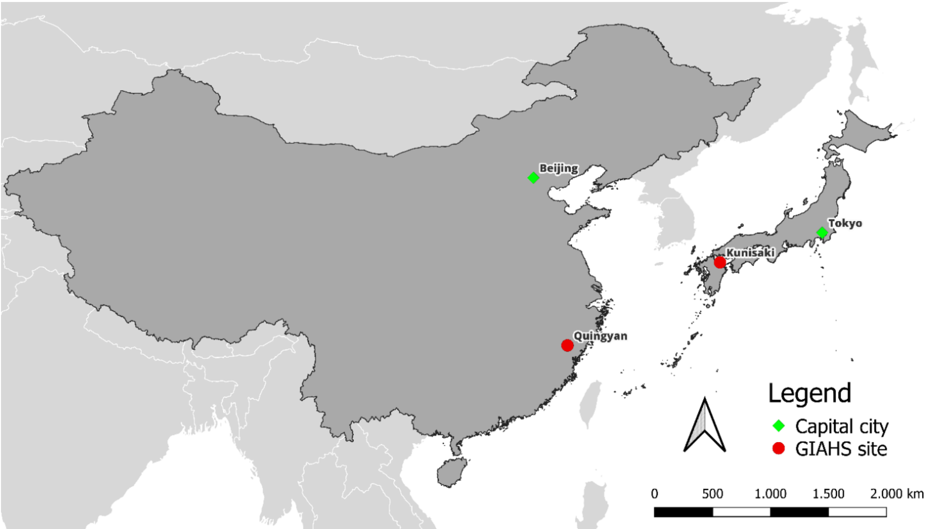

Fig. 1 The location of the two GIAHS sites: the Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System in Japan and the Qingyuan Forest-Mushroom Co-culture System in China

ests. Forests are traditionally managed as coppices in order to obtain logwoods for Shitake production. The coppicing usually takes place in autumn and the logged wood is pieced into 1-1.2 m logs. Two or three years after coppicing, a selection of the shoots is made by local farmers, leaving only 2 or 3 shoots for each stump. Holes are drilled into the cut logs and are inoculated with the fungi, a practice called *komauchi*, so that the shitake mycelium spreads inside the log (a process known as *fusekomi*). The logs (called *hoda-gi*) are kept in this condition till the following autumn when they are transported into areas (called *hoda-ba*) with a partial oak canopy cover that protect the logs from direct sunlight, but allows the right amount of indirect light and humidity for shitake growing. Shiitake mushrooms can be harvested twice a year: in spring and in autumn (GIAHS Promotion Association of Kunisaki Peninsula Usa Area 2013).

The Qingyuan Forest-Mushroom Co-culture System in Zhejiang Province (China) is located in Qingyuan County. While the area inscribed in the GIAHS Programme is only a small part of Qingyuan County, we decided to consider all the county as our study site as traditional forest management related to shitake cultivation is practiced also in all the county. The study site extends for about 189,000 hectares, with altitudes ranging from 232 to 1838 m a.s.l. Most of the area is covered by forests that are rich in wild fungi, with about 360 edible or medicinal species (Gu et al. 2019). The Qingyuan Forest-Mushroom system in Zhejiang Province has been recognized as the first area at global level for the artificial cultivation of mushrooms with a history of more than 800 years. The ancestors of Qingyuan people used to picked mushrooms in the forest for a living, but since the 12th century they started to cultivate and trade mushrooms, activities that allowed them to maintain a standard of living above the average of the neighboring areas almost until nowadays. Traditional shitake cultivation is carried out according to two different techniques. The first one is called *duohua*, and is based on cultivating shitake directly in the forest, while the second one is the wood-log technique and is the same carried out in the Japanese GIAHS site. According to the *duohua* technique, some trunks of different species are cut, not exceeding 15% of the total wood volume of the area, and applying a rotation of the forest plots; cracks are practiced with an axe on the felled trunk to favor the access of shitake spores and the spread of the mycelium, and then are covered with branches and leaves to protect them from direct sunlight and for maintaining relatively stable humidity; two years later, at the beginning of winter, trunks begin to produce bigger shitake suitable for the market and is time to remove the cover of branches and leaves, and to pick the mushrooms (The People's Government of Qingyuan County, Zhejiang Province 2022).

The traditional technique developed through the centuries by mushroom farmers (called *gumin*) of Qingyuan prevents the single cutting of a certain tree species or the over-cutting of certain woodlands, ensuring that the forest can renew naturally and therefore it represents a sustainable management and exploitation of forest resources (Zhu et al. 2022). The traditional knowledge accumulated by mushrooms farmers through the centuries in relation to forest conservation, management and utilization, as well as in mushroom cultivation, lead to the development of a system based on sustainable forest management and on circular bioeconomy. Nowadays, 46.9% of the local farmers' incomes comes from mushroom cultivation, therefore representing a crucial economic resource (The People's Government of Qingyuan County, Zhejiang Province 2022).

Materials

Different databases have been used to compare land uses among the two sites and among different periods.

For Japan, the High-Resolution (10 m) Land Use and Land Cover Maps have been downloaded as geotiff from the Earth Observation Research Center web site of the Japan Aerospace Exploration Agency[1]. The two land use maps refer to the periods 2006–2011 and 2018–2020. In fact, these datasets represent the average situation, not the specific situation in a specific year, but are really useful to check land use changes over time. Since they represent the average situation, in the present study we decided to refer to these land use databases as 2008 and 2019.

Concerning the Chinese GIAHS site, we used the 30 m resolution China's Land-Use/Cover Datasets (CLUD), produced by Yang and Huang (Yang and Huang 2021) using Landsat images from 1985 to 2019. To easily compare the results with the Japanese site, we decided to use the datasets of the years 2008 and 2019.

Administrative boundaries have been downloaded from GADM.org (Database of Global Administrative Areas) in December 2022.

A Digital Terrain Model (DTM) developed by the US Geological Survey (USGS) and the National Geospatial-Intelligence Agency (NGA) has been downloaded as geotiff tiles from EarthExplorer.usgs.gov. This DTM is the SRTM (Shuttle Radar Topography Mission) Void Filled type, with a resolution equal to 3 arc-seconds for global coverage (around 80–90 m).

Methodology

The methodological flow is summarized in Fig. 2.

[1] https://www.eorc.jaxa.jp/ALOS/en/dataset/lulc_e.htm.

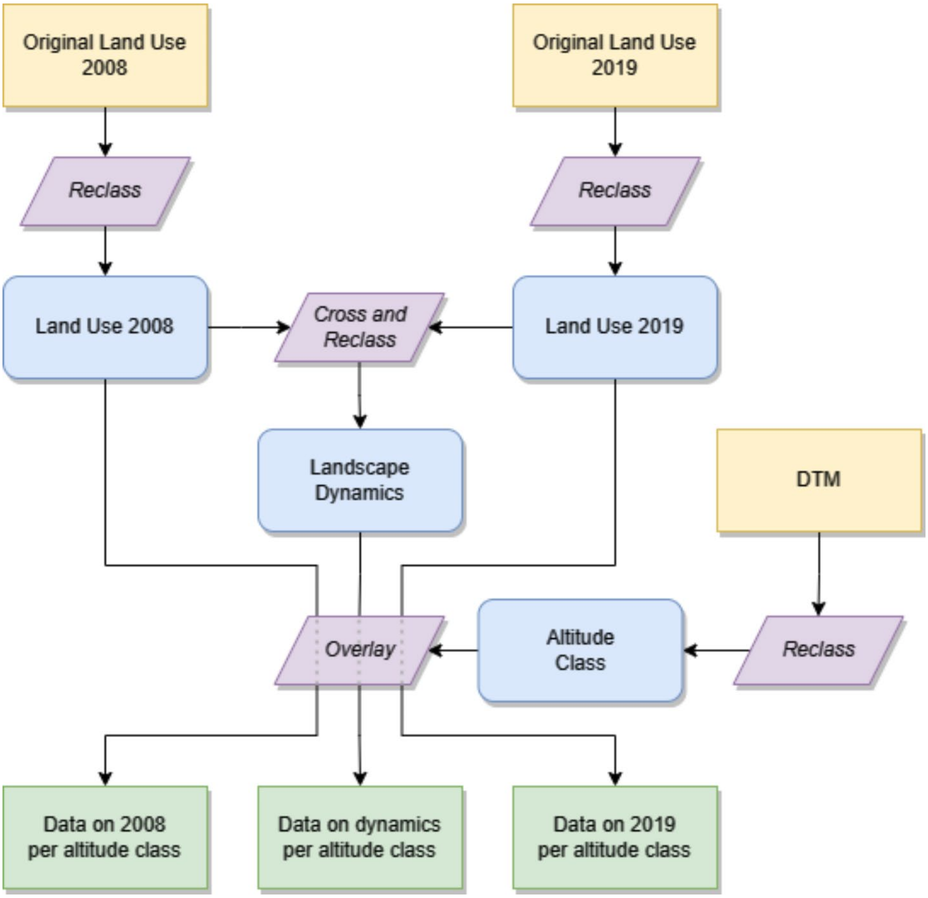

Fig. 2 The scheme of the applied methodology

The first part of the methodology focused on the realization of the land use maps for the two GIAHS sites to characterize the local landscape and to detect land use changes. All the following elaborations have been made using the software QGIS 3.22.3 and the GRASS 7 plug-in.

The first step has been the definition of the boundaries of the two study sites. The boundaries follow administrative borders, therefore, their delimitation has been made according to the administrative boundaries downloaded from GADM.org. After that, the land uses databases have been cropped according to the boundaries of the study areas, and statistical elaborations have been made for the different periods.

The land use datasets of the two countries have a similar legend, but with some differences. In Table 1 are reported the original land uses that can be found in the two GIAHS sites. In order to make the results easier to compare among the two sites, and due to some inaccuracies we found in the Japanese land use maps (see Sect. 2.4 for details), we decided to apply a simple reclassification.

Table 1 the original legends of the land use datasets for the Chinese and the Japanese sites, and the reclassification used for the spatial analyses

Japan land use legend	Chinese land use legend	Reclassified land uses
Built-up	Built-up (Impervious)	Urban area
Solar panel		
Cropland	Cropland	Cropland
Paddy field		
Grassland	Grassland	Grassland
Deciduous broad-leaf forest	Forest	Forest and shrubs
Deciduous needle-leaf forest		
Evergreen broad-leaf forest		
Evergreen needle-leaf forest		
Bamboo forest		
	Shrub	
Bare	Barren	Unproductive
Water bodies	Water	

The two datasets for each area have then been overlapped to detect land use changes in the considered time intervals. This approach follows the VASA (Historical and Environmental Approach) methodology, which is based on the comparison of land use maps of different years to measure landscape changes and trends in cultural landscapes, in order to assess landscape changes, the overall level of integrity, and the main vulnerabilities (Agnoletti et al. 2019). The analysis of the land use changes between the different time intervals allows to produce a new layer with new polygons, each of them including information about the land use in the past and at the most recent year. On the basis of this information, each polygon was then manually classified according to a standard classification, in order to identify the land use dynamic (Table 2). Moreover, the Sharpe Index has been calculated; this index highlights the intensity of the different processes of land use changes that occurred in the considered study area in the considered time interval (Sharpe et al. 1981). The Sharpe Index is applied to the single land uses and can take on a positive or a negative value. If the index assumes a positive value, it means that the considered land use increased its surface in the reference period, while if the value takes a negative sign the land use decreased in terms of overall surface. The resulting graph allows to identify the most relevant land use changes in terms of intensity. The Sharpe Index is calculated according to the following formula:

$$SharpeIndex = \left(\frac{pk_2 - pk_1}{t_2 - t_1}\right) / S$$

where: pk_1 is the surface of the land use pk at year t_1 expressed in hectares; pk_2 is the surface of the land use pk at year t_2 expressed in hectares; $t_2 - t_1$ is the time interval expressed in years ($t_2 > t_1$); S is the total surface of the study area expressed in km^2.

In order to evaluate the accuracy of the land use databases that have been used for this study, and to validate the results, it has been decided to carry out the validation analysis on the 2019 land use maps through random validation points and the use of QGIS 3.22.3. A square grid overlapping the study areas borders with sides equal to 2500 m has been created with the tool Create Grid. After that a random point has been set for each square of the grid with the tool Random Points in Polygons. This approach allows to have an evenly but random distribution of the points within the study areas. Due to the different size and shape

Table 2 The dynamics used for classifying the land use changes in the two GIAHS sites

Dynamic	Description
Unchanged	The main type of land use remains the same during the time interval, or when there is a change between similar land uses (i.e., among different types of forest cover).
Urban sprawl	Replacement of natural or agricultural land uses with urban areas, infrastructures, or buildings.
Intensification	The transformation from low-consumption land uses (in terms of biomass removal, mechanization, fertilizer, pesticides) to land uses characterized by high specialization and by a high need of energy supplies. It usually corresponds to the replacement of the traditional agricultural land uses with intensive agricultural land uses.
Extensification	The opposite of the previous dynamic, which is rarely linked to a return to traditional land uses, but more often is due to the abandonment of agricultural land uses replaced by uncultivated land.
Forestation	Process in which trees or shrubs occupy lands once used for agriculture or grazing.
Deforestation	Removal of forests or shrublands for obtaining land for agriculture or grazing.

of the two study sites also the final number of points falling inside the study area is different: 210 control points have been set for the Japanese study area and 313 for the Chinese one. Each point has been manually classified according on the base of high-resolution Google Satellite images of 2019. The results of the point classification have then been compared with the original raster land use maps to evaluate the percentages of points with the same land use to assess the accuracy of the raster maps. This has been carried out through QGIS 3.22.3 and the tool Sample raster values algorithm within the Raster analysis functions in the processing toolbox. Despite these limitations the use and comparison of different land use datasets is largely assessed in studies dealing with landscape and environmental changes, representing a crucial source of information to characterize certain landscape structures, and to investigate and understand the main trends as well as the main threat.

An additional in-depth analysis of the land use structure and changes according to the altimetry has been performed using QGIS 3.22.3 and GRASS7 plug-in. The first elaboration involved the reclassification of the DTMs into 200 m elevation classes. Subsequently, these elevation classes have been overlapped with land uses and dynamics to obtain the data subdivided by altimetry classes. The final produced datasets could also represent a baseline for future monitoring and planning.

Results

The land uses of 2008 and 2019 in the Japanese GIAHS site

Results of the land use analyses show that in both 2008 and 2019 most of the surface of the Kunisaki peninsula GIAHS site is covered by forests, followed by cropland and by urban areas (Table 3). Forests are mainly found in the internal part of the area, while agricultural areas occupy the portions closer to the seacoast and some long and narrow internal valleys that climb up on the slopes of the central mountain. Urban areas are mainly concentrated in some settlements located along the coast and scattered buildings are not so widespread. Grassland are rare and mainly represented by small scattered patches (Fig. 3). This is also evident from the distribution of the land uses according to the altimetry (Fig. 4). Forests are the most widespread land use in all the altimetry classes, but they are more common above 200 m a.s.l. For both the considered years, 94% of cropland surface is mainly located at altitudes lower than 200 m a.s.l., but it is important to highlight that more than 1,400 ha in 2008 and more than 1,500 in 2019 of cultivated areas are found also above 200 m a.s.l.; the preservation of cultivated areas at higher altitudes is important as they contribute to the preservation of the traditional *satoyama* landscape of the hills and to water regulation. Urban areas are mainly found (98% in 2008 and 95% in 2019) in the class 0-200 m a.s.l. while they are very rare at higher altitudes, as only 102 ha in 2008 and 247 ha in 2019 are located above 200 m a.s.l.

Table 3 Land uses in 2008 and 2019 for the Japanese GIAHS site

LAND USE	2008		2019	
	Surface (ha)	Surface (%)	Surface (ha)	Surface (%)
Urban area	4,799	3.63	5,342	4.04
Cropland	25,187	19.03	24,114	18.22
Grassland	2,930	2.21	4,780	3.61
Forest	97,503	73.66	96,195	72.67
Unproductive	1,956	1.48	1,944	1.47
TOTAL	132,375	100.00	132,375	100.00

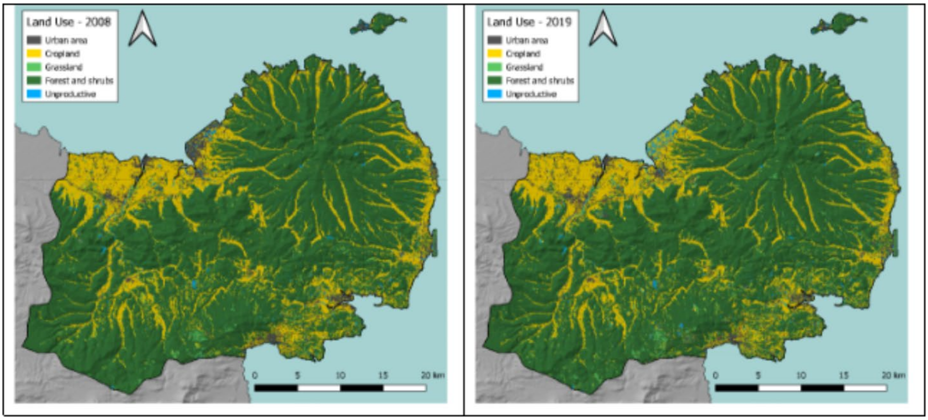

Fig. 3 Land use maps for 2008 (a) and 2019 (b) for the Japanese GIAHS site

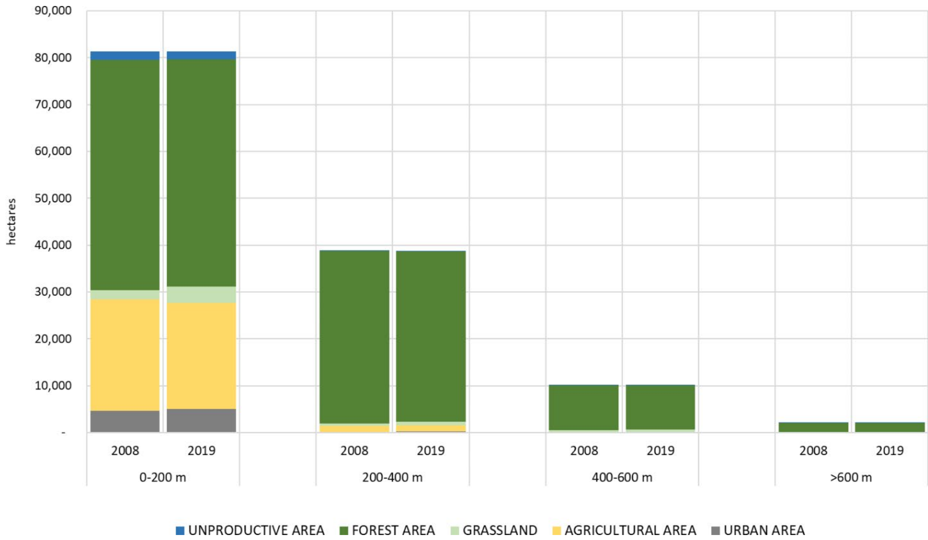

Fig. 4 Analysis of the land use distribution according to the altimetry classes for the Japanese GIAHS site

The land uses of 2008 and 2019 in the Chinese site

Results of land use elaboration highlight that forest is definitely the main land use for Qingyuan county, occupying more than 96% of the total surface in 2008 and about 95% in 2019 (Table 4). Despite the limited overall surface, croplands (2.98% in 2008 and 4.43% in 2019) represent important features of the local landscape, and they can be principally found along the main valleys or surrounding the scattered villages in the mountains (Fig. 5). Regarding the altitude, in 2019, 42% of the surface of croplands is located below 400 m a.s.l., but it is important to highlight that 34% is in the range 400–1000 m a.s.l. and that 10% is above 1000 m a.s.l., testifying that traditional agriculture is still important not only in the valley floor, but also around the small mountain villages (Fig. 6). Urban areas have a limited overall surface, but the percentage growth exceeds +65% in only 11 years; it is possible to identify two different types of settlements: bigger urban agglomerations in the valleys and scattered villages in the more rural and mountainous part of the study site. Urban agglomerations correspond to the contiguous area between Qingyuan and Pingduzhen in the central part of the study site, and to the villages of Huangtianzhen and Zhoukouzhen in the north-western part of the study site. Grasslands are not so common in the study area as only small scattered patches can be found, testifying that grazing activities are not part of the local traditional practices.

The landscape dynamic in the period 2008–2019

The overlapping of the two land use maps and databases for each study area lead to interesting findings. The Chinese site seems to be more stable regarding the land use changes in the last 11 years, considering that the percentage of unchanged surface is equal to 96.9% against 89% resulting from the analysis of the Japanese GIAHS site (Table 5). But it is necessary to analyze the data more in detail to identify the main trends.

Table 4 Land uses in 2008 and 2019 for the Chinese site

LAND USE	2008		2019	
	Surface (ha)	Surface (%)	Surface (ha)	Surface (%)
Urban area	673	0.35	1,122	0.59
Cropland	5,650	2.98	8,389	4.43
Grassland	205	0.11	168	0.09
Forest	182,905	96.52	179,740	94.85
Unproductive	76	0.04	87	0.05
TOTAL	189,508	100.00	189,508	100.00

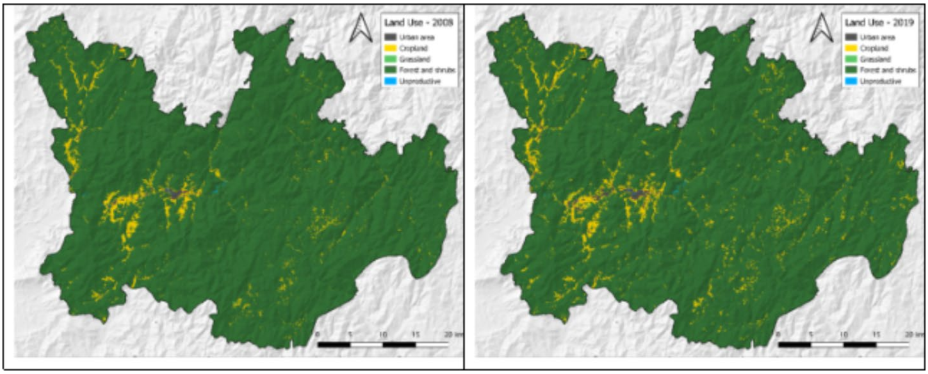

Fig. 5 Land use maps for 2008 (a) and 2019 (b) for the Chinese site

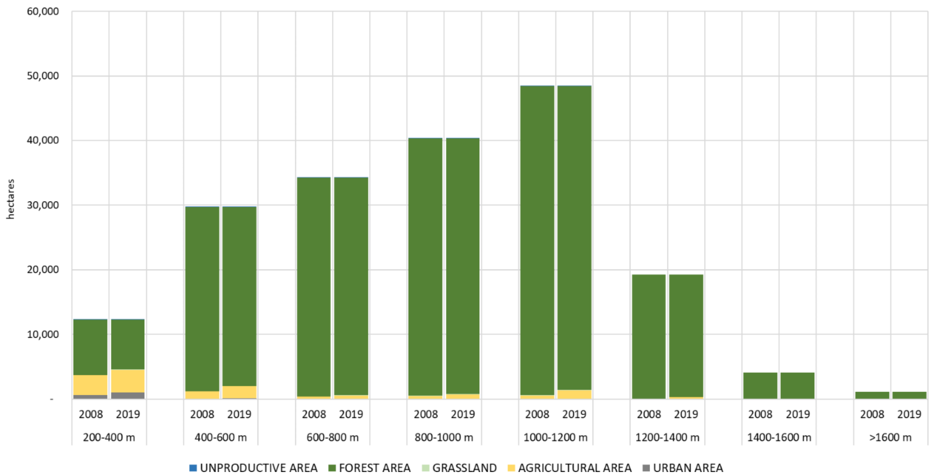

Fig. 6 Analysis of the land use distribution according to the altimetry classes for the Chinese site

In the Kunisaki peninsula, the two dynamics related to the abandonment of agricultural areas (estensivization and afforestation) are found on 6,796 ha, meaning that the abandonment of agricultural surface (-4.3%) and consequent reforestation through secondary successions proceed at a rate of about 618 ha/year (Fig. 7); part of this abandonment is balanced by the deforestation occurring on 3,884 ha. Urban sprawl mainly occurred due to the expansion of the main town outskirts or to the spread of solar panels in rural areas and even if

Table 5 Landscape dynamics in the period 2008–2019 for the Japanese and the Chinese site

LANDSCAPE DYNAMIC	Japan		China	
	Surface (ha)	Surface (%)	Surface (ha)	Surface (%)
Unchanged	118,259	89.3	183,575	96.9
Afforestation	3,091	2.3	1,077	0.6
Deforestation	3,884	2.9	4,145	2.2
Intensivization	1,324	1.0	68	0.0
Estensivization	3,706	2.8	104	0.1
Anthropization	2,112	1.6	527	0.3

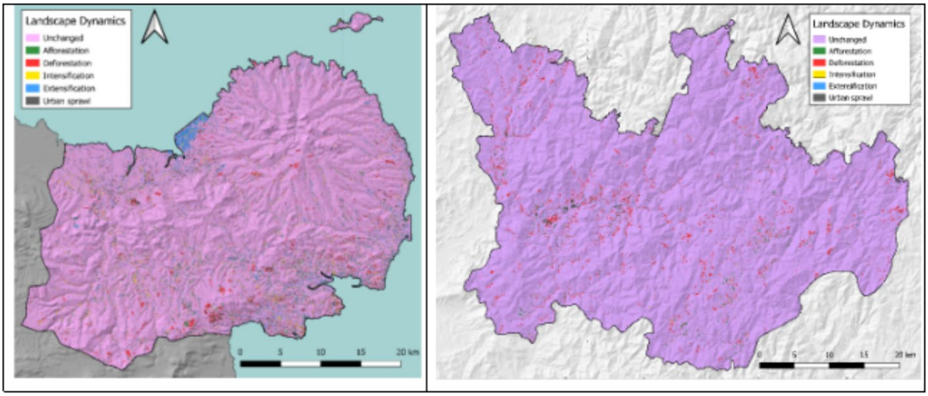

Fig. 7 Landscape dynamics maps for the Japanese (a) and the Chinese sites (b)

the total surface affected by this dynamic is equal to 1.6% of the total area it is necessary to consider that it proceeds at a rate of 192 ha/year. Most of the changes (81% of the changed surface) identified for the Japanese GIAHS site took place in the altitude range 0-200 m a.s.l., while the situation is relatively stable at higher altitudes (Fig. 8).

Regarding the Qingyuan Forest-Mushroom Co-culture System, the analysis of the data allowed the identification of some characteristics trends. Deforestation is found on 4,145 ha and is only partly balanced by afforestation that occur on about 1,000 ha. This means that, even considering the opposite effect of the new forests on abandoned lands, the rate of deforestation is equal to 280 ha/year. This deforestation is evenly spread among the different altitude classes lower than 1200 m a.s.l. (Fig. 8) and is caused by the spread of croplands; agricultural surfaces, in the period 2008–2019, pass from 5,650 to 8,389 ha (+250 ha/year), therefore, representing a major trend regarding landscape changes within the study area. Another trend that have potential impacts on the local landscape integrity in the near future is urban sprawl; even if in terms of overall surface the urban sprawl is limited, it is important to highlight that in only 11 years urban areas doubled their surface, mainly in the outskirts of the bigger settlements of the county, as testified by the altitude analyses since 86% of this dynamic take place in the lowest altitude class. The areas above 1200 m a.s.l. do not present significant changes regarding land uses.

The Sharpe's Index for the period 2008–2019 confirms some of the aforementioned identified trends in terms of relevance and intensity (Fig. 9). Deforestation is a common issue, but it has a major relevance in the Chinese study areas, where it is not balanced by second-

Fig. 8 Analysis of the landscape dynamics in percentage according to the altimetry classes for the Japanese and the Chinese sites

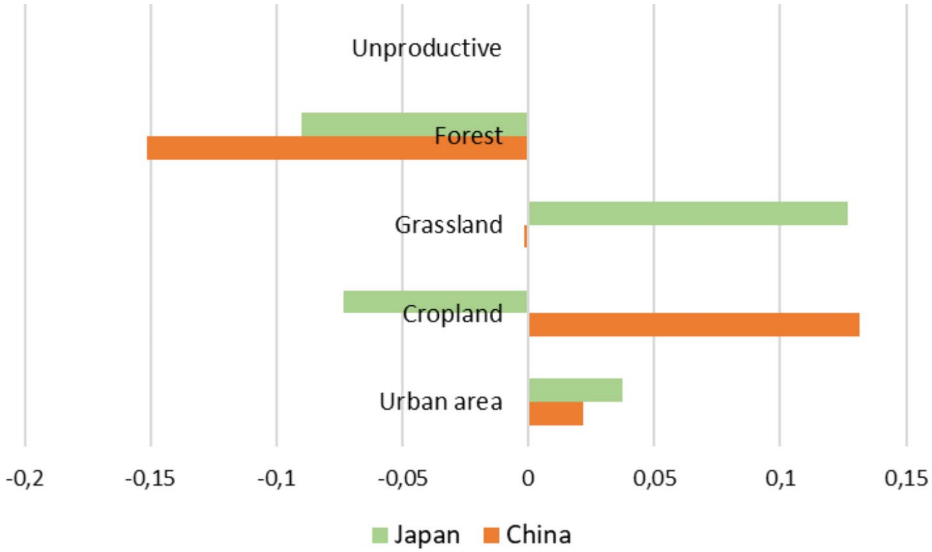

Fig. 9 Sharpe Index for the period 2008–2019 for the Japanese and the Chinese sites

ary successions on abandoned croplands. Grassland are increasing in Japan, probably due to the abandonment of some marginal cultivated areas, as confirmed by the value of the index related to croplands. Croplands are instead increasing their surface in China and are the main responsible of deforestation. Urban areas are spreading in both sites with similar values of the Sharpe Index.

The accuracy assessment

The results of the accuracy assessment are quite different for the two sites and the two land use maps. The assessment performed on the Japanese High-Resolution (10 m) Land Use and Land Cover Maps 2018–2020, returned an accuracy percentage equal to only 84.3%. For the Chinese 30 m resolution China's Land-Use/Cover Datasets (CLUD), the returned value was instead equal to 92.3%. The main reasons for low value of accuracy of the Japanese land use map is probably related to the fact that the dataset represent an average situation between 2018 and 2020, not a specific situation in a specific month and year, while the accuracy assessment has been made on specific satellite images of April 2019. Therefore, this discrepancy may have led to a lower accuracy value. In addition, it is known that the Japanese High-Resolution (10 m) Land Use and Land Cover Map has some inaccuracy issues, even if with our reclassification of the land uses the level of inaccuracy has been reduced respect to what is reported in literature (Takahashi et al. 2013). In both cases, it is possible to consider that the results of this assessment are a confirmation of the reliability of the findings of this study, also considering that accuracies above 85% are considered satisfactory for planning and management purposes (Rozenstein and Karnieli 2011).

Discussion

Even if a part of the production of shitake in China and Japan is nowadays conducted with industrial and modern techniques, the traditional production carried out in forests and also mushrooms collection from wild woodlands are still important as the quality of the final product from traditional production techniques is considered to be higher (Arora 2008; Yang et al. 2008). In addition, it necessary to consider that the traditional log-cultivated method is much more sustainable respect to the modern cultivation on sawdust. The traditional log-cultivated method is based on renewable and natural sources, it is capable of producing high quality shitake and contributes to a sustainable forest management; the modern sawdust medium-cultivated method, instead, is based on the high input of non-renewable resources and has a greater impact on the environment, but lower costs (Gu et al. 2019). The rapid growth of the mushroom business in China and Japan and the current relevance of the traditional log-cultivated method is a great example of rural economic development and of and sustainable forestry based on traditional knowledge. These are also the main reasons that explain why the FAO more than 10 years ago already started to actively promote mushroom cultivation for sustainable rural development and food security, especially in developing countries (Marshall and Nair 2009).

Our research findings demonstrated that the land use structure of the two study areas remained almost unaltered in the last 10 years, but the applied methodology also allowed to identify some pressures that can represent a possible threat for the future regarding preservation of the traditional landscape structure, if not adequately addressed by local planners and institutions.

In the Kunisaki peninsula particular attention should be paid to the areas at altitudes lower than 200 m a.s.l., as they are the ones that are suffering from major land use changes.

The main pressure is due to the abandonment of agricultural surface (-4.3%) and consequent spread of grasslands (+63%) and reforestation (+1.3%) through secondary successions. The main reasons are related to the social situation of the agricultural sector, and more in general of the Japanese society. Depopulation and aging are in fact two major threats for the preservation of traditional forest management and related shitake production within the GIAHS site, considering that the number of farming households fell from 18,000 to around 13,000 in the period 2000–2010, and that about 70% of people relying on farming as the main source of livelihood are over 65 years of age (GIAHS Promotion Association of Kunisaki Peninsula Usa Area 2013). These trends are in line with the situation at national level, considering that in the last 20 years the aging society and the low fertility rate are causing a critical depopulation of rural areas, leading to land use changes, land abandonment and underuse of local natural resources, with consequent declining of the overall sustainability, of ecosystem services and of traditional *satoyama* landscapes (Shoyama et al. 2019; Kobayashi et al. 2020; Sasaki et al. 2021). Urban sprawl is still limited considering the total area affected by this dynamic, but results of the research highlighted an urban sprawl rate of 192 ha/year, meaning that this trend needs to be addressed for the future of the site, in particular along the urban-rural border. In addition, a part of this dynamic is related to the spread of solar panels, a trend common also to other rural areas in the country that can have negative consequences on the aesthetic value and on the landscape perception, especially within a recognized GIAHS site (Piras et al. 2022). Another treat within the GIAHS site is represented by climate change, that in the last years is forcing many producers to replace the traditional *teion-hinshu* shitake variety ("low-temperature variety") that sprouts at low temperatures or when stimulated by a drop in temperature, with middle-temperature shitake varieties (Miyake and Kohsaka 2022).

Qingyuan County represents the largest mushroom market and the largest mushroom trading center at national level, with more than 70,000 people engaged and with an annual output of more than 100,000 tons and about 300 edible mushroom enterprises (Wang et al. 2020). Even if mushroom cultivation is not threatened by the risk of abandonment, some land use changes have been detected by this research. Deforestation and expansion of new cultivated lands are the main land use changes, that occurs both around the bigger cities in the main valley and, with less intensity, around the sparse rural settlements, as demonstrated by our analysis of the land use changes according to the altitude classes. The other main pressure regarding the traditional landscape has been identified by this study in the urban sprawl, equal to +67% in 11 years. Rapid urbanization and industrialization, together with the introduction of modern technologies for shitake production and relative shortage of labour force for traditional shitake production are also confirmed by other sources (The People's Government of Qingyuan County, Zhejiang Province 2022).

The results of this research demonstrated that also the traditional landscape structure of the two sites is different, partly due to the morphology. In Kunisaki Peninsula, cultivated areas are found in the narrow valleys along the mountain slopes, surrounded by forests. This strong functional and spatial arrangement between forests and croplands that deeply characterize the structure of the local landscape and also creates a variety of habitats, can be considered an example of a traditional Japanese rural landscape, called *satoyama* (Kobori and Primack 2003). In Qingyuan County cultivated areas are not interspersed among forests, but traditionally surrounds the small rural villages or can be found along the main valley floor, probably due to a more rugged morphology. In both cases, it is really important to preserve the historical landscape structure with the spatial and functional relations between agriculture and forests.

The Qingyuan Forest-Mushroom Co-culture System is not the only GIAHS site in Zhejiang Province, as other two exists, and according to Xingguo et al. (2021) common vulnerabilities can be found, including imperfect management, low participation of residents, and lack of special protection funds. Among the suggestions provided by the same authors for Zhejiang Province GIAHS sites, the development of specific branding for traditionally-produced agricultural products can effectively support farmers who still adopt traditional agroforestry practices, and therefore, support the traditional and sustainable forest management at county level.

Another important role related to the preservation of the traditional logwood method for shitake production and for the related forest management can be played in both of the GIAHS sites by sustainable rural tourism. According to Nomura et al. (2018) in the Kunisaki peninsula GIAHS site, the combination of sustainable rural tourism with payments by users of the touristic trails and with contributions through volunteer activities can have positive effects on the preservation of traditional forest activities. The situation in China is quite different. In Qingyuan County tourism is not evenly distributed; while central areas are commonly visited by tourists, marginal and more forested ones suffer a lack of touristic infrastructures, but the construction of transportation infrastructures to promote regional tourism networking and increase the acceptable travel time of tourists desired by Bojie et al. (2020) can also lead to overtourism and related problems, such as the abandonment of traditional forest management by local farmers in favor of more profitable touristic-related activities (restaurants, accommodation, guides) (Drápela et al. 2021; Boh 2022). In this sense the promotion of slow-tourism models can represent a more efficient and sustainable strategy to promote sustainable rural development in sparse rural villages (Serdane et al. 2020) than the construction of new infrastructures.

The results of this research also highlighted that traditional log-based shitake cultivation can have a key role for promoting an active, sustainable and economically interesting forest management, even in other countries beside China and Japan. This was already recognized more than 10 years ago by Gold et al. (2008), who reported that forest-cultivated shitake provided good incomes for US farmers, contributing in increasing the managed woodlots value and resulting to be a good integration for agroforestry systems. In fact, it is necessary to consider that the traditional production method based on wood logs started to be spread outside the historic production area (China, Japan, Korea) already 40 years ago (San Antonio 1981), especially in western countries, with good economic results, while received comparatively little attention in developing countries, especially in tropical ones, despite the suitable environmental conditions (Salmones et al. 1999). Reasons for the spreading outside of the historic production area of traditional log-based shitake cultivation are mainly related to high market values, an increase in importation of dried mushrooms by Japan, and recognized medicinal properties, especially as antitumoral, anti-inflammatory, and antioxidant (Flyn 1991; Mori and Thakehara 1989; Rahman and Choudhury 2012). In addition, despite the fact that from the ‘80s several attempts have been made to promote shitake cultivation on sterilised or pasteurised substrates in order to increase yield and reduce the time of its culture cycle (Delpech and Olivier 1991; Levanon et al. 1993; Przybylowics and Donoghue 1988; Royse et al. 1985), and that even wireless sensors have been tested for real time monitoring of temperature, humidity and CO_2 (Kassim et al. 2017), traditionally produced shitake mushrooms are recognized to have a higher quality and market value and, therefore, can still provide good incomes for farmers, contributing to the sustainable management of forest resources.

Data resulting from GIS elaborations of land use datasets created with different methodologies and referring to different periods must be used and understood considering possible causes of inaccuracy (Stäuble et al. 2008; Rumsey and Williams 2002). The main cause is related to the fact that these datasets have been produced using different methodologies, level of detail, classification, spatial accuracy, source of information, and tools. The period of the year in which satellite images were taken can also affect the land use classification. Another limitation comes from the fact that the land use maps we used in this research are produced through an auto classification of satellite images. The High-Resolution Land Use and Land Cover Maps of Japan have some accuracy problems related to specific land uses, in particular in distinguishing between the different types of forests and between cropland and paddy field (Fig. 10). This is an already recognized critical issue, as reported by Takahashi et al. (Takahashi et al. 2013) who highlighted low accuracy percentages for 2006–2011 land use map for the aforementioned land uses, based on approximately 2,500 validation points. This explains why it was necessary to proceed with a land uses reclassification, as it is better to have a lower level of detail, but higher levels of accuracy and relevance to reality.

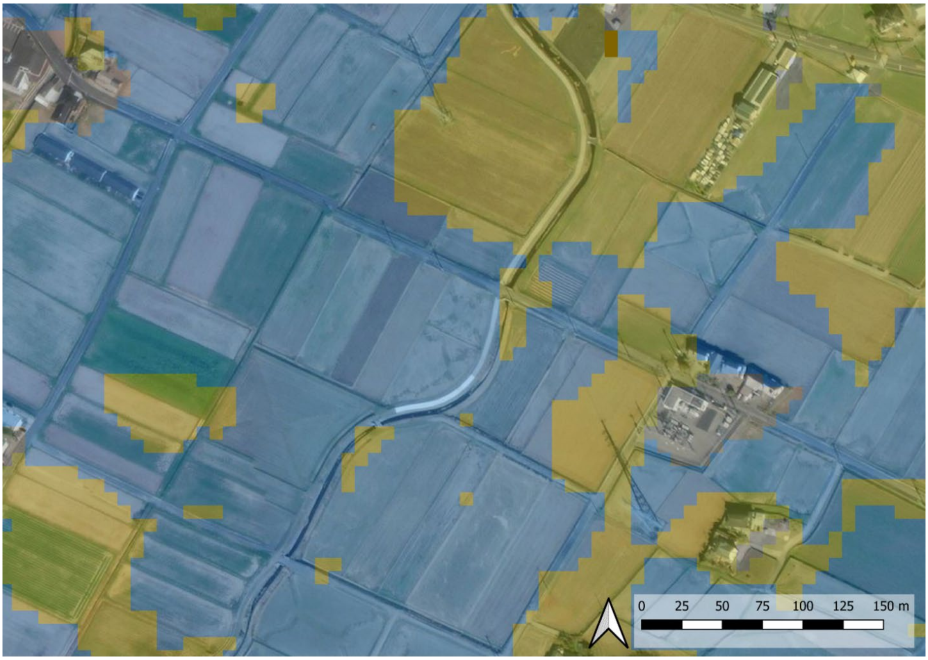

Fig. 10 It is possible to observe that the distinction between cropland (yellow) and paddy field (light blue) reported by the Japanese High-Resolution Land Use and Land Cover Map do not correspond to the real situation. The same happens for the different types of forests

Conclusions

The preservation of traditional forest-related practices and management models is not only crucial for the conservation of specific cultural forests, with their species composition, vertical and horizontal structure and related NWFPs, but it also contributes to the preservation of the overall traditional landscape structure and of landscape-scale biodiversity. The applied methodology demonstrated that in the two FAO-recognized systems, the continuation of traditional forest management, economically supported and justified by the production of high-quality shitake mushrooms, has effectively contributed to the preservation of two different but both traditional landscape structures in the last 10 years. Despite the fact that most of the surface of the study sites do not present significant land use changes during the last 10 years, the methodology has also allowed to identify some threats that may affect the two GIAHS sites in the future, including abandonment or intensification of agriculture, deforestation, urban sprawl. In addition, socio-economic transformations at local and regional level could favor the abandonment of traditional forest management, that does not immediately reflect in a land use change, but can lead to a change in the cultural forest structure, in terms of specific composition, structure and functionality. The main limitation of the study is related to the accuracy of the land use databases and on the reduced time interval that has been analyzed, but the reclassification carried out in the first phase of the methodology turned out to be effective in improving the accuracy of the original land use maps. The findings of the study represent a key dataset for future monitoring, but also for local and national planners and for the GIAHS secretariat, as monitoring GIAHS sites is crucial to evaluate the effectiveness of the Programme itself.

The preservation of the strict relations between cultural forests, agricultural surfaces and rural villages, in terms of spatial arrangements and functional relations, is crucial both for the cultural landscapes of FAO-recognized sites and for the related ecosystem services. The study highlighted that the preservation of cultural forests, of the traditional landscape mosaic and of biodiversity at the landscape scale cannot be detached from the maintenance of traditional forest management. In addition, it is necessary to consider that in the two sites traditional forest management has represented an example of sustainable exploitation of local resources for producing high-quality NWFPs that economically supported local farmers and communities for centuries. The actual global challenges in terms of climate change and sustainable exploitation of natural resources, can take advantage of the study of traditional systems and practices. Rural tourism could play a significant role in improving farmers' incomes and in supporting shitake market, but it should be considered that in fragile environments overtourism turned out to be a threat rather than a resource, i.e. due to overexploitation of water, pollution or overcrowded trails. Therefore, further studies should be carried out to assess the potential threats and opportunities related to rural tourism and to promote sustainable tourism. Future monitoring of land use changes will also be crucial for properly addressing local and regional policies and strategies. Traditional forest management, if adequately integrated with other economical activities, can contribute to the sustainable rural development, being able at the same time to combine the production of high-quality NWFPs, the preservation of cultural landscapes, the differentiation of the incomes sources for local farmers and new job opportunities for younger generations, with the preservation of local natural resources and of the local cultural heritage and sense of place.

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Data Availability The datasets generated during and/or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests The authors have no relevant financial or non-financial interests to disclose.

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