forests

Review

A Review of the Role of Forests and Agroforestry Systems in the FAO Globally Important Agricultural Heritage Systems (GIAHS) Programme

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Abstract: Traditional agroforestry systems have received increasing attention in recent decades for their multifunctional role and as a sustainable development model for rural areas. At the international level, the Food and Agriculture Organization (FAO) launched the Globally Important Agricultural Heritage Systems (GIAHS) programme in 2002 with the aim of identifying agricultural systems of global importance; preserving landscapes, agrobiodiversity and traditional knowledge; applying the dynamic conservation principles while promoting sustainable development. The aim of the research is to carry out a review of the inscription dossiers of all the 59 sites already included in the GIAHS programme, in order to analyze the role of forests and agroforestry systems. Moreover, the main traditional management techniques have been identified and briefly described, as traditional forest-related knowledge is particularly important for sustainable forest management. Forests and agroforestry systems have been found to be important or crucial in about half of the sites. The main role assigned to forests and agroforestry systems in GIAHS proposals is related to the production of timber, fuelwood and by-products for the local communities according to sustainable and traditional management techniques. Among these, they also play important roles in hydrogeological protection, water regulation and biodiversity maintenance, representing examples both of human adaptation to different environments and of resilient systems that could help to face global challenges such as hydrogeological risk and climate change. The review of the GIAHS inscription dossiers also highlighted the lack of a uniform approach in dealing with forest issues, especially for what concern the description of management plans and the relation with protected areas or forest planning instruments.

Keywords: agricultural heritage; agroforestry; FAO; GIAHS; rural landscape; sustainable forest management

1. Introduction

Nowadays, rural areas are facing numerous challenges in economic, social, cultural and technological fields, together with climate change and its consequences. The development and the spread of productive models promoted in the last decades has not only shown to be ineffective at solving the problems of many rural areas, but, especially in Europe, it has also contributed to the loss of cultural values associated to communities' traditions [1,2]. In fact, the model based on increasing agricultural productivity, established after the 1950s, among the numerous consequences, has caused the degradation of valuable landscapes shaped by several generations of farmers as the result of their adaptation to the surrounding environment [3]. In Europe, this has produced the abandonment of millions of hectares of farmland considered difficult to be cultivated or maintained using new machineries and, as a consequence, it has created problems like soil erosion, habitat degradation and a loss of biodiversity [4–6]. In the same way, recent deforestation, estimated to be 13 million ha/year [7], occurring mostly in Asia and South America, to obtain wide portions of farmland to be cultivated as intensive monocultures, has caused soil erosion and wild flora and fauna habitat degradation too [8–10].

For these reasons, the use of sustainable ecological practices related to traditional agricultural systems is a key feature to prevent such consequences which are negative both for environmental and life quality. In addition, traditional agricultural practices represent a valid alternative to support climate change mitigation while maintaining traditional systems and cultural values. This kind of farming may be considered less productive than modern-intensive systems, but it has ensured a sustainable yield over time [8].

Based on this idea, in 2002, the Food and Agriculture Organization (FAO) of the United Nations launched the Globally Important Agricultural Heritage Systems (GIAHS) programme. This programme focuses on the identification and safeguard of agro-silvo-pastoral sites that have retained traditional techniques and are still providing many services to the ecosystem, while maintaining traditional landscapes, agrobiodiversity, ancestral knowledge transmitted through generations and strong cultural and social values. Located in specific sites around the world, GIAHS sites sustainably provide multiple goods and services, food and livelihood security for millions of small-scale farmers while contributing to climate change mitigation, applying the dynamic conservation principles [11]. GIAHS sites are representative of local traditions constituting both a fundamental heritage and a valid alternative to support local communities' economies. The GIAHS programme, and the aim to recognize and collect all these sites, has the purpose of monitoring the maintenance of their peculiarities and to spread the related traditional knowledge so that they could represent a worldwide recognized example of sustainable management.

Traditional forest practices and agroforestry systems are nowadays spread all over the world and their multifunctional roles are widely recognized. Probably the most complete definition of agroforestry is the one given by the Food and Agriculture Organization (FAO), that resumes the one of World Agroforestry (ICRAF) [12], even if recently new definitions more focused on the social role have been proposed [13]. The FAO definition affirms that "agroforestry is a collective name for land use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence. In agroforestry systems there are both ecological and economical interactions between the different components." According to the same definition, agroforestry can be considered as multifunctional systems that integrates trees and agriculture, creating peculiar landscapes, diversifying the productions and increasing the environmental and economic benefits for local communities. The relation of agroforestry systems with smallholder farmers is of crucial importance, since it can increase their food supply, income and health.

Agroforestry systems have been in use for at least 1300 years according to pollen records [14], although tree domestication probably started earlier [15]. In recent decades, traditional agroforestry systems and traditional forest-related knowledge all over the world have received increasing attention by decision makers, conservation and development organizations, and scientific communities. Forest-related knowledge is "a cumulative body of knowledge, practice and belief, handed down through generations by cultural transmission and evolving by adaptive processes, about the relationship between living beings (including humans) with one another and with their forest environment" [16].

Since the early 19th century, the introduction of modern forestry led to the application of different management techniques with the aim of increasing timber production. These ideas were spread throughout the world during the 19th century, also through the colonial administrations of European imperial powers, leading to significant transformations for many cultural forest landscapes all over the world created by traditional preindustrial societies [17–19]. In the 1970s, forest management started to pay greater attention to the ecological role of forests and to biodiversity but, considering the latter is only in relation to "natural" environments, the role of humans is often perceived as a disturbance factor. The result of these orientations and of consequent policies was a difficult relationship between the forest practices of traditional communities and those of forest science. From the '90s, it has been recognized that the equity of knowledge between local communities' forest-related traditional knowledge and formal forestry scholars could be successful for a sustainable forest management [20].

In recent years, traditional agroforestry systems and forest-related traditional knowledge have received increasing attention, both at scientific and political levels, in relation to their multifunctional role and as a sustainability-enhancing practices that combine the best attributes of forestry and agriculture. Today, their importance is mainly based on the fact that they can represent examples of adaptation and resilience to the changes occurring in rural areas and to climate change [21–27]. In fact, despite the fact that agroforestry systems can have some minor negative effects (labor-intensive, competition between different species for natural resources, amount of biomass production), they could be a strategically beneficial in rural planning and sustainable rural development in terms of land use [28].

Forests and agroforestry systems have always played a fundamental role for rural communities' economy, contributing multiple benefits according to different agroecosystem features. Therefore, even among the sites in the GIAHS programme, forests and agroforestry systems are characterized by different degrees of importance: in some cases, the landscape is the result of a close interaction of forested and cultivated patches, while some other forests play only a minor part inside their agroecosystem.

The aims of this paper are to carry out a review of the role assigned to forests and/or agroforestry systems in the different sites currently in the GIAHS programme and to provide an overview of the different forest structures, species and traditional management techniques of each site. Evaluating the importance and the function assigned to forests and agroforestry systems in GIAHS sites, as well as identifying the associated traditional knowledge, is particularly important, both for their multifunctional role and for sustainable forest management. Examples from different countries around the world could help to understand how forests and agroforestry systems are considered in one of the most important international programs related to the conservation of traditional landscapes, agricultural practices and agrobiodiversity. This programme is in fact based on dynamic conservation principles and the sites are considered examples of sustainable human adaptations to different environments and climate change. Moreover, the results of this paper could provide some suggestions for the future of the GIAHS programme in relation to the consideration and monitoring of forest-related issues.

2. Materials and Methods

A review of all the application files to the GIAHS programme has been carried out in order to obtain detailed information about the wood importance and its influence on the systems. As of March 2020, there are 59 sites in the GIAHS programme and many of them can be classified as agroforestry systems; 39 of them are in Asia, 9 in Africa and the Middle East, 7 in Europe and 4 in Central and South America.

The first step focused on distinguishing if forests and/or agroforestry systems were considered important or not in each GIAHS site proposal in order to exclude from the analysis the sites where forests and/or agroforestry systems are not present or where they play a marginal role. We analyzed all the 59 inscription dossiers and we decided to distinguish different levels of importance, assigning a score, from 0 to 3, to each site:

0: Forests and/or agroforestry systems are not part of the GIAHS site;
1: Forests and/or agroforestry systems are integrated in the GIAHS site but they do not have a considerable functional role;
2: Forests and/or agroforestry systems are one of the features that characterize the agro-ecosystem and they play an important functional role;
3: Forests and/or agroforestry systems are a distinguishing element of the GIAHS site, as they represent the main features and the main functional role.

The second phase consisted of an in-depth study of the structure and management characteristics of the sites labelled with scores equivalent to 2 and 3. The aim of the second phase was to better understand the role of forests and/or agroforestry systems and which are the different ways of protection and management considered in each nominated area. In particular, we decided to evaluate the following roles, assigning a score from 0 to 3, based on the consideration resulting from the GIAHS proposal:

- timber, fuelwood, food and by-products (fodder, fibre);
- biodiversity;
- landscape;
- hydrogeological protection.

Forests and/or agroforestry systems in fact, can assume different roles, both for the environment and for the local communities. We decided to focus on these four criteria, as they are the most easily identifiable as the dossiers for the GIAHS program describe the site according to the 5 GIAHS criteria: food and livelihood security; agrobiodiversity; local and traditional knowledge systems; cultures, value systems and social organizations; landscapes and seascapes features (http://www.fao.org/giahs/become-a-giahs/selection-criteria-and-action-plan/en/).

Information about "timber, fuelwood, food and by-products (fodder, fibre)" can be found in the GIAHS criteria food and livelihood security and local and traditional knowledge systems. Information about the role of forests and/or agroforestry systems for the local "biodiversity" are included in the criteria agrobiodiversity. The role of forests and/or agroforestry systems for the local "landscape" is instead included in the criterion of landscape and seascape features, while the role of forests and/or agroforestry systems for "hydrogeological protection" is a cross-cutting theme that can be described in the criteria local and traditional knowledge systems, landscape or in the part about the global significance.

Together with the assigned scores, a brief description of the forest structure, species and traditional management techniques of each site is reported in the following chapter.

It is important to underline that, since the vector information related to the site boundary delimitation is not required, the evaluation of the characteristics of each individual site was carried out only through the documentary information available and through an accurate bibliographic research, and not by the interpretation of aero-photos or satellite images. Consequently, it was not possible to measure and quantify the surfaces.

3. Results and Discussion

The scores given to each GIAHS site according to the importance assigned to the forests and/or agroforestry systems is reported in the Appendix A. A total of 11 sites are classified with a score of 0 (18.6%), 19 with a score of 1 (32.2%), 15 with a score of 2 (25.4%) and 14 are classified with a score of 3 (23.7%). This means that about half of the site forests and/or agroforestry systems play an important or crucial functional role.

According to the geographical distribution of the results it is possible to highlight some differences (Figure 1): Central, South American and European sites are the ones where the importance of forests and/or agroforestry systems is lower, since agroforestry systems are less frequent in the GIAHS sites located in these parts of the world.

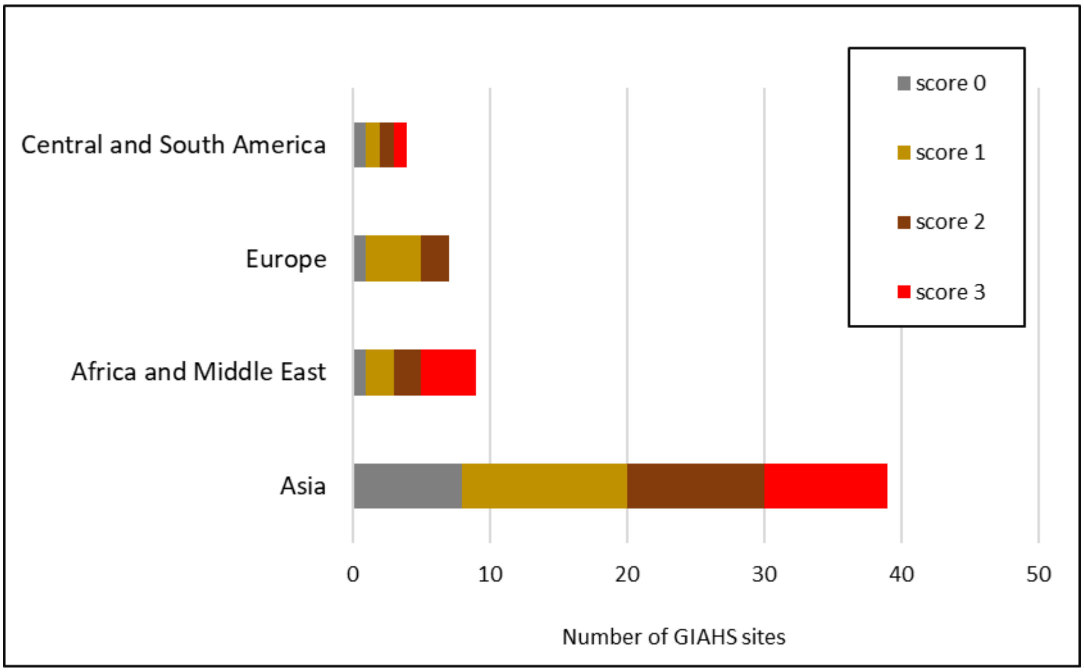

Figure 1. Number of Globally Important Agricultural Heritage Systems (GIAHS) sites according to the geographical location and to the scores.

The second phase of the study is an in-depth analysis of the role assigned to forests and/or agroforestry systems according to their hydrogeological protection and water regulation, landscape, timber and fuelwood, by-products and biodiversity. Moreover, an analysis of the management and of the structure of forests and/or agroforestry systems has been carried out. The main results are summarized in Table 1.

Table 1. Evaluation of the role of forests and agroforestry systems according to the analysis of the GIAHS proposals for four different indicators, and main structural and management characteristics.

Area	Country	Name of GIAHS Site	Hydrogeological Protection and Water Regulation	Landscape	Timber, Fuelwood, Food and By-Products (Fodder, Fiber)	Biodiversity	Structural/Management Characteristics
Asia	China	Jiaxian Traditional Chinese Date Gardens	2	2	3	2	Jujube plantations/Intercropping and fruit harvest
	China	Fuzhou Jasmine and Tea Culture System	2	2	1	3	Subtropical forest/Use of pine, eucalyptus and bamboo Tea and jasmine agroforestry system/Leaf collection
	China	Traditional Mulberry System in Xiajin's Ancient Yellow River Course	3	2	2	2	Mulberry and fruit tree agroforestry system/ Agronomic treatments
	China	Pu'er Traditional Tea Agrosystem	3	3	3	2	Primary forests/Free evolution, harvest of fruits Tea trees/Leaf collection and manual weeding, thinning
	China	Kuajishan Ancient Chinese Torreya	3	2	3	2	Torreya grandis plantations/Protection of seedlings, harvest of fruits Evergreen subtropical forests/ Differentiated management
	China	Xinghua Duotian Agrosystem	2	3	1	3	"Water forest"/Free evolution
	China	Diebu Zhagana Agriculture-Forestry-Animal Husbandry Composite System	2	3	3	3	Conifer forest/Forestry based on single tree cuttings Poplars and willows near the houses/Pruning
	Japan	Noto's Satoyama and Satoumi	2	2	3	1	Konara (Quercus serrata) and other broadleaf forests/Coppice for charcoal Traditional paulownia and cypress plantations/Selective cuts for boat production Modern cypress, cedar and pine plantations/ Classic forestry
	Japan	Ayu of the Nagara River System	3	3	2	1	Forests broadleaves or conifer species/Utilization cuts, thinning, planting to maintain high quality water
	Japan	Minabe-Tanabe Ume System	3	2	2	2	Quercus phillyraeoides forests/Coppice and selective cutting for coal production Other mixed broadleaf forests/Free evolution
	Japan	Traditional Wasabi Cultivation in Shizuoka	3	3	1	1	Wasabi-Alnus hirsuta agroforestry system/Agronomic treatments

Table 1. *Cont.*

Area	Country	Name of GIAHS Site	Hydrogeological Protection and Water Regulation	Landscape	Timber, Fuelwood, Food and By-Products (Fodder, Fiber)	Biodiversity	Structural/Management Characteristics
	Japan	Nishi-Awa Steep Slope Land Agriculture System	3	3	3	1	Protection forests/Free evolution Other forests/Cuts for timber production, cultivation of shiitake, edible wild plants
	Japan	Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System	3	3	3	2	Quercus acutissima forest/Coppicing for growing shiitake mushrooms on trunks
	Japan	Takachihogo-Shiibayama Mountainous Agriculture and Forestry System	3	3	3	2	Forests and plantations of various conifer and broadleaves species/"Itinerant forestry", stubble burning on cycles of 30–50 years—Sustainable forestry management (FSC certified)
	Japan	Osaki Kodo's traditional water management system for sustainable paddy agriculture	2	3	3	3	*Igune*, floating forests of different species/Thinning, selective cuts, harvest of fruits and leaves
	Philippines	Ifugao Rice Terraces	3	2	2	2	Mixed broadleaves forest/Protection forest or choice cutting for self-consumption and for commercial purposes
	Korea	Traditional Gudeuljang Irrigated Rice Terraces in Cheongsando	3	2	1	1	Forests of Korean fir/Grazing in the woods, occasional cutting
	Korea	Geumsan Traditional Ginseng Agricultural System	2	2	2	1	Subtropical forest/Thinning, occasional cutting
	Sri Lanka	The Cascaded Tank-Village System in the Dry Zone of Sri Lanka	3	2	3	3	Tropical forest and agroforestry homegardens/Occasional cutting and harvest of fruits, leaves, roots.
Africa and Middle East	Algeria	Ghout System (Oases of the Maghreb)	3	1	3	0	Date palm oasis/Harvest of fruits, wood and leaves as building material
	Morocco	Oases System in Atlas Mountains (Oases of the Maghreb)	2	1	2	1	Cold oases with different tree species/Cuttings and pruning for timber and firewood
	Morocco	Argan-based agro-sylvo-pastoral system within the area of Ait Souab—Ait Mansour	2	3	3	3	Sparse argan forest (*Argania spinosa*)/Harvest of fruits
	Egypt	Dates production System in Siwa Oasis	0	3	3	3	Date palm oasis/Harvest of fruits, wood and leaves as building material

Table 1. *Cont.*

Area	**Country**	**Name of GIAHS Site**	**Hydrogeological Protection and Water Regulation**	**Landscape**	**Timber, Fuelwood, Food and By-Products (Fodder, Fiber)**	**Biodiversity**	**Structural/Management Characteristics**
	Tanzania	Shimbue Juu Kihamba Agroforestry Heritage Site	3	3	3	3	Humid tropical mountain forest/Grazing of small animal in the woods, harvest of fruits, occasional cutting
	Tunisia	Gafsa Oases (Oases of the Maghreb)	0	3	3	3	Date palm oasis/Harvest of fruits, wood and leaves as building material
Europe	Portugal	Barroso Agro-Silvo-Pastoral System	1	3	3	2	Forests of oak and pine/Forest grazing, cuttings for biomass
	Spain	Salt production system of Añana	0	2	3	2	Forests of oak and pine/Cuttings for timber wood
Central and South America	Mexico	Chinampas Agricultural System in Mexico City	3	1	2	1	*Salix bonplandiana* around the chinampas/Pruning of branches
	Brazil	Traditional Agricultural System in the Southern Espinaço Range, Minas Gerais	3	2	3	3	Traditional homegardens; Forests for medicinal plants, fruits, fibers, oils, wood/Forests are managed partly for slash-and-burn and partly conserved for water regulation

3.1. Central and South America

In Central and South America, there are two sites where forests or agroforestry systems play an important or crucial role for the site.

The first one is the Chinampas Agricultural System in Mexico City (score 2), where artificial islands (chinampas), 20 m long and 1.2 m wide, used for agriculture, are surrounded by *Salix bonplandiana* (*ahuejote*), whose branches were also used for building the container for the chinampas themselves. The tree's extensive secondary roots create a compact mesh that contains the chinampa's perimeter, avoiding erosion and stabilizing its edges, while the primary roots fix the chinampa to the bottom of the lake. Nowadays, the *Salix bonplandiana* are less important than in the past as new construction of chinampas is occasional and the leaves and branches are rarely used as fodder for livestock [29].

The other site is the Traditional Agricultural System in the Southern Espinaço Range (Minas Gerais, Brasil), where can be found both agroforestry systems (traditional homegardens) and forests. Local homegardens are characterized by a great diversity of vegetables (several of them native), medicinal herb crops, fruit trees and crops (cassava, beans, squash, peanuts, sugar cane, potatoes, yams, coffee and others). Small animals are also raised in homegardens (chickens, rabbits and local breeds of pigs), whose manure is used as fertilizer, in addition to a few cows for the family's milk, and beehives. Local forests are partly managed through traditional slash-and-burn, and partly are conserved for water regulation. In both cases, forests provide medicinal plants (83 different species), fruits (35 species), fibers, oils and timber (16 species) used to build local houses and facilities [30].

3.2. Europe

There are two European sites where forests and/or forest trees play an important role in the agricultural system, the Barroso Agro-Silvo-Pastoral System in Portugal and the Salt production system of Añana in Spain.

In Barroso, the main activity is livestock farming (cattle, goats and sheep) carried out in pastures with a tree cover mainly made of *Quercus pyrenaica* and, occasionally, *Quercus robur* [31]. Agroforestry management not only allows direct animal grazing, but also represents a source of vegetal material used as animal bedding which later, after decaying in stalls, can be applied to arable land in order to fertilize agricultural crops. These forests are also a source of firewood used for home heating by the local people, so their role is particularly important for landscape and timber, firewood and by-products.

In Añana Valley, thanks to the local geological characteristics, a number of saltwater springs emerge at the highest part of the valley. This saltwater is channeled through a system of canals to salt pans, by the force of gravity, where it evaporates to form salt. The slopes of the valley are covered with forests that are particularly important for water regulation and that were (and still are) the main source of wood for building the salt-pans and the channels, so that the management of the local forests is strictly connected to the functioning of the traditional salt production system and to the preservation of the local traditional landscape [32,33].

3.3. Africa and Middle East

A total of six GIAHS sites in Africa and the Middle East, are characterized by forests and/or forest trees that play an important role or that are a distinguishing element of the GIAHS site. Two of them are classified with a score of 2, the Ghout System (Oases of the Maghreb) in Algeria and the Oases System in the Atlas Mountains (Oases of the Maghreb) in Morocco. The other four GIAHS sites are classified with label 3, and are Argan-based agro-sylvo-pastoral systems within the area of Ait Souab-Ait Mansour (Morocco), the Shimbue Juu Kihamba Agroforestry Heritage Site (Tanzania), the Dates Production System in Siwa Oasis (Egypt) and the Gafsa Oases (Oases of the Maghreb (Tunisia)).

The Ghout System in Algeria is a traditional irrigation system for oases. Even though these oases are mainly characterized by a traditional layout based on date palms, they represent an agroforestry system, and the proposal mainly focuses not on the management of the oases but on the irrigation system. So, this is particularly important for water regulation, as well as agricultural products and dates, even if in the proposal palms are also mentioned in relation to agrobiodiversity and landscape [34,35].

In the High Atlas Mountains of Morocco, cold oases connected to rangelands and collective grazing areas have been created by Amazigh people despite extreme climate conditions. These oases are mainly used for cereals, legumes, vegetables and fruit trees, in addition to livestock breeding, but the presence of sparse trees is also important. The main tree species used by local populations are *Populus alba*, *Populus nigra*, *Tamarix gallica*, *Nerium oleander*, and *Salix* spp. In fact, as well as food production, these agricultural systems are capable of providing firewood for the heating of the local houses, however in the last few years the demand for timber and firewood has increased and it is no longer sustainable, also due to overgrazing that affects renovations [36].

The argan forest (*Argania spinosa*), locally called *arganeraie*, is part of the semi-arid Mediterranean area in southwest Morocco and is included in the UNESCO program Man and the Biosphere Reserve (MAB) [37]. This system contributes to the maintenance of soil fertility, is important for hydrogeological and desertification protection and for biodiversity, and is a fundamental resource for the local population [38]. The argan tree forest density varies from around 30 trees/ha to over 80 trees/ha [39] and the argan fruit is considered a multi-user fruit. The dry pulp constitutes a significant food reserve for animals, broken hulls are used as energy fuel by the local population, and the kernel, the extraction residue of argan oil is used in animal feed [40]. However, argan oil is its main product. Its extraction is exclusively a female activity through cooperatives, and it is traditionally used as a cooking oil or as a cosmetic oil, but since the 1990s its demand on international markets has been continuously increasing.

The Shimbue Juu Kihamba agroforestry system in Tanzania has been identified as one of the best examples of a resilient system for agriculture in mountain areas. It occupies the most climatically favorable southern and eastern foot slopes of Mount Kilimanjaro covering an estimated area of 120,000 ha [41], at an altitude between 1000 and 1800 m. The Kihamba homegardens are characterized by four main layers of vegetation, forming a structure very similar to that of a tropical forest, maximizing the yield of the plots. The uppermost layer is formed by sparsely spaced trees which provide shade, medicine, fodder, fruits, firewood and timber. Under this layer more than 15 varieties of bananas are grown. Under the bananas there are coffee shrubs (introduced by the missionaries during the German colonial period in the early 1880s) and under these, vegetables of variable species, including climbers, are grown. Most of the tree species are remnants of the former forest cover, such as *Albizia schimperiana*, *Rauvolfia caffra*, *Cordia africana*, *Commiphora eminii* and *Margaritaria discoidea* [42].

Gafsa in Tunisia and Siwa in Egypt are two examples of traditional oases, based on traditional water management and on an agricultural system that can be divided into three levels [43]. The lower is used for fodder, cereals and vegetables cultivations. Then at the intermediate level, olive trees and fruit trees, including local varieties, are grown. At the upper level, there are date palms, providing shadow to the lower levels. Traditional oases have a rich agrobiodiversity, not only for the different plant species that are cultivated, but also for the number and for the conservation of local varieties of date palms [44,45]. Date palms are not important only for the landscape and the biodiversity of the oases, but also for creating a microclimate for the lower cultivations and for providing wood and leaves that are locally used as building materials.

3.4. Asia

In Asia, 11 GIAHS sites have been classified with a score of 2 according to the role of forests and/or forest trees, and 9 with a score of 3. Eight sites are in China, eight in Japan, two in the Republic of Korea, one in the Philippines and one in Sri Lanka.

In many Asian sites, forests are considered crucial for their role in hydrogeological protection and in water regulation. It is the case of different terraced landscapes, such as the Ifugao Rice Terraces (Philippines), where private (*muyung*) and municipal forests (*ala*), are mainly located at the upper fringes overlooking the rice terraces, and they regulate the impact of precipitations and nutrients from rainfall slowly releasing them to the rice terraces below [46]. In the Traditional Gudeuljang

Irrigated Rice Terraces in Cheongsando (Korea), between the sixteenth and mid-twentieth centuries, local communities built stone aqueducts used for underground irrigation that connects the forests of the mountain area (71% of the surface of the GIAHS site) which retain water for most of the time with the area of the settlements downstream. The mixed deciduous forests surrounding the Minabe-Tanabe Ume (*Prunus mume*, Japanese apricot) system (Wakayama Prefecture, Japan) GIAHS site, have the important function of conserving water and soil, regulating the water source for the ume orchards, replenishing nutrients and preventing landslides; moreover, this *Quercus phillyraeoides* forests provide a high quality charcoal, called *Kishubinchotan*, through a selective-cutting method of coppice forest management, not found in other places, which can regenerate the trees quickly, and the forests are also home for the bees that pollinate apricot trees in spring, feeding on their nectar, since many ume varieties of this site cannot self-pollinate [47]. The management of the forests of the Nagara river valley (Gifu Prefecture, Japan)—mainly composed by broadleaves like Japanese chinquapin (*Castanopsis cuspidata*), Japanese blue oak (*Quercus glauca*), Siebold's Beech (*Fagus crenata*), Japanese oaks (*Quercus crispula*, *Q. serrata*) or conifers, such as Japanese red pine (*Pinus densiflora*), Japanese cedar (*Cryptomeria japonica*) and hinoki Cypress (*Chamaecyparis obtusa*)—is instead aimed at preserving a high water quality, allowing the survival of the Ayu fish (*Plecoglossus altivelis altivelis*), but also the possibility of having clean water to drink and for irrigating the fields [48].

In other cases, forests and/or trees can have a specific protection role. The Osaki Kodo's traditional agroforestry system (Miyagi Prefecture, Japan) is characterized by *igune*: small forests composed of a high variety of species planted on the northwestern side of farmhouses in the middle of lowland paddies in order to protect houses from winds. As well as wind protection, they represent a source for daily sustenance: lower branches and fallen leaves become fuel and compost, thick branches and tree thinning are used for wooden crafts and as fuel, fruit and nuts and plant shoots provide food, camellia and Japanese nutmeg provide seeds from which oil can be extracted, while other plants are used for medical purposes and higher trees provide building material or firewood. Major tree species are cedar, bamboos, *Neolitsea sericea*, hinoki cypress, camellia, Japanese spindle, black pine, Japanese persimmon, Japanese zelkova, chestnut and Japanese alder, and when rice fields are flooded, *igune* form an archipelago of forest islands floating on the water, creating a unique landscape [49]. In the Xinghua Duotian Agrosystem (Jiangsu, China), trees resistant to humidity such as the pond cypress (*Taxodium ascendens*) and the dawn redwood (*Metasequoia glyptostroboides*), have been planted in the 1980s to protect cultivations and to provide wood to support crops on the water; nowadays, these "water forests" offer impressive sceneries and are important habitats for birds and crucial for the livelihood maintenance of local people [50].

Forests and/or forest trees traditional management can also provide a wide range of products to the local communities. In Diebu Zhagana's system (Gansu, China), local forests, mainly of conifer species, including the protected *Taxus chinensis*, provide food for pigs that are sent to graze, logs for house construction and firewood for heating, fertilizers such as bedding and wood ash, and around 88 species of medicinal and edible fungi are found in local forests together with medicinal herbs [51]. Poplars and willows have been planted near the houses also as a protection from wind. Moreover, forests guarantee the conservation of soil, intercepting precipitations and reducing the erosion, also thanks to a management linked to Tibetan culture, that provides a series of taboos relating to all elements of the landscape that prevent water loss, soil erosion and ecological imbalance that could derive from the over-exploitation of the woods and desertification of the grasslands. The dense subtropical forests surrounding the Fuzhou tea and jasmine agroforestry system (Fujian, China) in recent decades have experienced unprecedented pressures regarding the demand for wood resources [52], and in this regard the Fujian Province has completed a reform based on the collective management of forests [53]. As well as dense subtropical forests, Chinese red pines (*Pinus massoniana*), treated with clearcutting with a 31-year shift and thinning in the middle of the rotation period, and *Pinus taeda* plantations are found together with eucalyptus and bamboo managed by small owners through very short shifts [53]. The subtropical forests surrounding the Geumsan Traditional Ginseng Agricultural System provide natural shade and microclimate control, through lowering the temperature, as well as construction material for the structures necessary for ginseng cultivation; moreover, thinned trees, humus, and wild grasses from the forests are used to make landfill and cover the shading structures, or as organic compost for ginseng cultivation. The Noto's Satoyama and Satoumi agroforestry system (Ishikawa, Japan) consists of a holistic approach to rice cultivation, fishing, agriculture and forestry. Local *konara* forests (*Quercus serrata*) are managed through coppicing, since the Muromachi period (1333–1573), for charcoal production; of the 10 to 20 shoots that sprouted from the stump, three or four would be selected for maturation, branches of saplings were also trimmed to ensure straight vertical growth, and once a tree reaches 20–25 years of age, it can be cut, and the cycle would start again. Local bamboo forests were instead managed for making oyster rafts for oyster farming, while the floats for fishing nets were made from paulownia or Japanese cypress, and trees along rivers and streams, called *uotsukirin* (literally forests connected to fish), were maintained by fishing communities to sustain healthy breeding and feeding grounds along the coastal waters. Here, the management of forests is still based on *iriai*, collective management committees of common lands and coastal waters, and forest management is based on very small-scale forestry [54–56]. The Nishi-Awa Steep Slope Agricultural System (Tokushima Prefecture, Japan) is characterized by a composite mosaic of forests and cultivated terraces [57]. The practice of leaving the forest intact near the ridge (*hachigo-giri*) above the village, helps preserve the slope stability, reducing soil erosion and regulating water sources, but they also provide timber, wood for fences and edible wild plants used in local cuisine, while in some forests can be found specific plants—such as shiitake mushrooms, *Edgeworthia chrysantha* used to make Japanese paper, or *Toxicodendron vernicifluum* used to make lacquer—that are collected and sold.

In some cases, peculiar and ancient forestry management systems are still practiced. In the Mountainous Agriculture and Forestry System of Takachihogo-Shiibayama (Miyazaki Prefecture, Japan) local communities apply a silvicultural practice called "itinerant forestry", consisting of the burning of small plots (0.5–1 ha) of forest, followed by a cultivation for some years, and then apply forest recovery techniques for 20–30 years, or even as many as 50 years. After that, the forest is cleared again. In the same place, forests are also managed with sustainable forestry practices and some villages adopted regulations aimed at preserving the forest resources, such as avoiding the transfer of the forest property to external landowners, so that these forests are nowadays FSC (Forest Stewardship Council) certified.

In other cases, the focus of Asian GIAHS proposals is on pure agroforestry systems. The Jiaxian traditional jujube agroforestry system (Shaanxi, China) is based on jujube (*Zizyphus jujuba*) and sour jujube (*Zizyphus spinosa*) cultivation, with the oldest plants having an estimated age of 1400 years and the diameter of the largest plants is more than 3 m. Jujube trees form ecological niches for other crops: when the trees are young the farmers plant short-stem crops, like potatoes, soybeans, rice, green beans, yams and vegetables, and when the trees are 6 to 7 years old, the farmers raise poultry under the trees, and when the plants grow, farmers intercrop them with grapes, pears, apples, apricots and vegetables. In the traditional Mulberry agroforestry system of Xiajin county (Shandong, China), mulberry trees are cultivated together with other fruit trees (peaches, plums, pears, apricots, jujubes, pomegranates and persimmons) or herbaceous crops (peanuts, sweet potatoes, cotton, wheat, cucumber, onion and beans) and they can provide important ecosystem services [58]. The Kuajishan Ancient Chinese Torreya (*Torreya grandis*) agroforestry system (Zhejiang, China) is managed mainly through grafting, used to improve the quality and production of Torreya fruits; here, the canopy of the Torreya trees cultivated between 300 and 600 m, creates a microclimate that allows the cultivation of vegetables (beans, potatoes, etc.), crops (wheat, corn, etc.), fruit trees (plum, waxberry, cherry, etc.), tea plants or medicinal herbs [59].

The Pu'er Traditional Tea Agrosystem (Yunnan, China) includes wild, domesticated or cultivated tea trees (*Camellia sinensis*). Wild tea tree populations are areas in which tea trees dominate the composition of the forest and play particular functional roles, with trees ranging from 4 to 45 m high, with diameters at breast height ranging from 0.3 to 1.43 m. Domesticated tea populations are the nuclei of tea trees older than 1000 years, which testifies to the domestication phase and the first human activities related to tea production. Cultivated tea forests generally have three layers: the higher consists of tall shading trees (mainly camphor trees, pine trees, fir trees, osmanthus trees and fruit trees) and remnants of the natural vegetation, selected by the farmers according to their function (pest control, improving the tea flavor, protection of water, soil and ecosystem, supply of food and medicinal herbs, firewood); the intermediate layer is made by tea trees and shrubs, and the lower one includes natural herbs, cereal or vegetable crops [60].

The Traditional Wasabi Cultivation in Shizuoka (Japan), is characterized by the ancient cultivation of wasabi (*Eutrema japonicum*), a brassicacea that needs particular environmental conditions: abundant rains, which generate dense and fertile forests, low temperatures and very steep terrains [61]. Wasabi is cultivated in small irrigated fields (with 1 to 2 cm of water covering the soil), often terraced, under the shade of trees (mainly *Alnus hirsuta*) that helps in maintaining a constant water temperature. The dense coniferous protection forests (mainly Japanese cedar and Japanese cypress) on the slopes around the wasabi fields are crucial parts of the systems, as they contribute to water regulation. In addition to wasabi, shiitake mushrooms are cultivated in the shade of the forests, while tea and rice are cultivated in the sunny areas outside of the forests.

In the Integrated Forestry, Agriculture and Fisheries GIAHS site of the Kunisaki Peninsula (Oita Prefecture, Japan), a complex system of which forests and agroforestry systems are a fundamental part characterizes the area. The main element of the agroforestry system is the sawtooth oak (*Quercus acutissima*), in the shade of which Shiitake mushrooms are produced. In fact, Shiitake mushrooms are traditionally cultivated on a substratum made of sawtooth oak log wood (called *Hoda-ba*). Other sawtooth oak forests are managed through a 15-year based coppice cycle [62,63].

The Cascaded Tank-Village System of Sri Lanka is characterized by a system of water reservoirs used to support agricultural and domestic activities, through storing, conveying and utilizing water. Forests and agroforestry homegardens are an integral part of the system, as they are crucial for water regulation and for providing a variety of products to local communities, such as firewood, timber, medicinal plants, fruits, nuts, seeds, leafy vegetables to the local diet, roots, barks, seeds to extract edible oils, resins, latex, and honey [64,65].

The results showed a great variability in structure characteristics as well as in management techniques. Calculating the average values in the different geographical areas (Figure 2) for the different criteria, it is possible to notice that regarding the landscape and biodiversity there are no big differences, even if it is necessary to consider that the number of the analyzed GIAHS sites is not the same for the four geographical areas. Forests and agroforestry systems are considered important for the landscape and reach only slightly lower values for biodiversity. Higher values are reached for timber, firewood and by-products production, especially in Europe and in Africa and the Middle East. In fact, in European GIAHS sites, it seems that the role of forests and agroforestry systems is more important for their productive role than for their hydrogeological protection and water regulation ones, as it happens in African and Middle East sites. Europe still preserves a lot of different traditional agroforestry systems, especially linked to silvo-pastoral practices, that are often linked to high-quality food production [66]. Asian GIAHS sites and Central and South American, instead, consider the role of forests and agroforestry systems fundamental for hydrogeological protection and water regulation. It is, for example, the case of many terraced sites where tea or rice represent the main cultivation, that forests that grow on the steepest slopes and on the upper part of the mountains above the terraced fields are essential for regulating the water availability to the cultivated field, avoiding too-intense flows and prolonging the time of water availability.

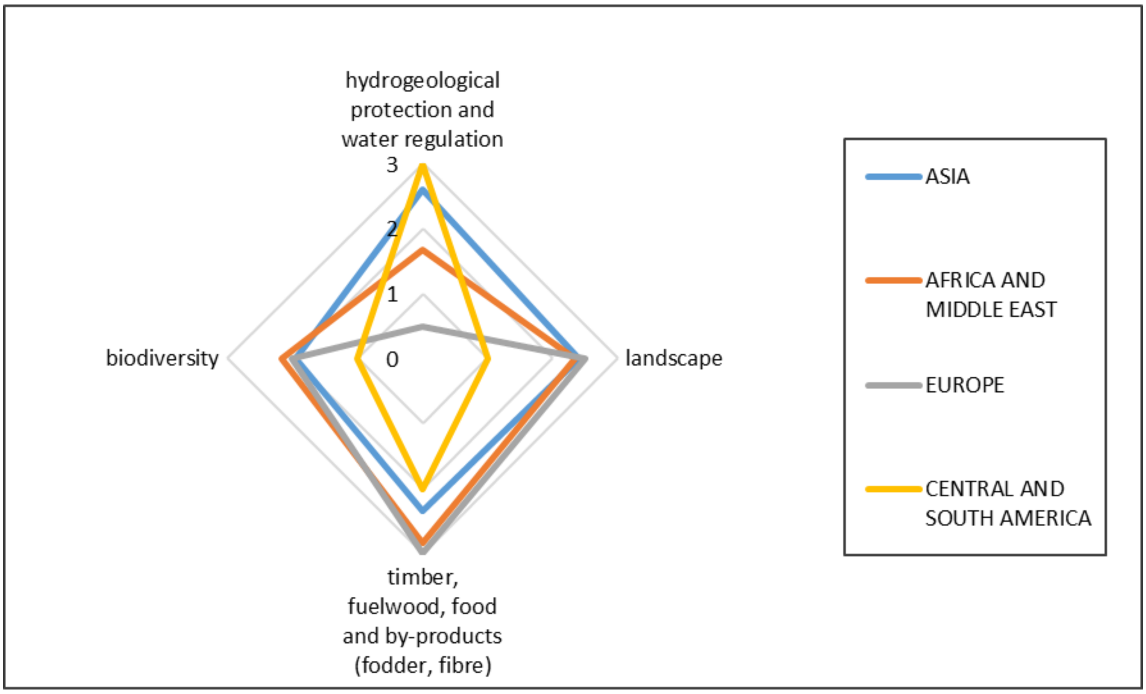

Figure 2. Average values for the different geographic areas according to four criteria.

4. Concluding Remarks and Suggestions

Summarizing, the role of trees can be categorized into three different types. The first one is the forests' role in reducing hydrogeological risks and the regulating water supply, which can mainly be found in sites characterized by steep slopes of terraced cultivations. The second type is a productive role—as well as providing timber and firewood, forests and trees are important for rural communities' livelihoods as they offer a high variety of products. The third type is linked to pure agroforestry systems, where the trees can provide a microclimate for under-canopy cultivations and/or other products and services to the local communities. In many sites, forests and pure agroforestry systems can be found at the same time.

The analysis of the GIAHS dossiers has also highlighted different traditional management techniques. Some of them are slowly disappearing mainly due to social and economic changes, but most of them are still practiced and are fundamental for the preservation of the characteristic features of the sites. The analysis of all the GIAHS dossiers highlighted that, regardless of the main role assigned to forests and agroforestry systems, the consideration assigned to forest-related traditional knowledge is high, since these roles are commonly considered to be achievable if traditional techniques survive. The weak point is that the functions and the application of the traditional management techniques are often not described adequately. It must be noticed that in most cases, the first purpose of the application of forest-related traditional knowledge is not to provide only timber or fuelwood, but to carry out a management aimed at maximizing the sustainable use of resources among which byproducts are particularly important. This is confirmed by different studies, especially in Asian countries, where the application of forest-related traditional knowledge seems to be more widespread [67,68].

The main threat for forests and agroforestry systems, beside the abandonment of traditional management techniques, is the increasing separation between forests and agricultural practices. Obviously, this is not happening in all the sites, and in the pure agroforestry systems this problem is more occasional. However, in many sites, the agricultural activities are not any more strongly linked to forest management. For examples, in the Korean Geumsan Traditional Ginseng Agricultural System, the local forests used to provide materials for building the structures necessary for ginseng cultivation, but in the last few years, the natural and traditional structures are more and more replaced with artificial material. In the last decades in some Japanese sites, where forests were also managed in order to obtain high quality charcoal, the decrease in charcoal demand has led to a change in forest management and structure. In other cases, the overexploitation of forest resources, such as in the Ifugao Terraces in the Philippines, has led to serious hydrogeological problems. Pure agroforestry systems, instead, have a high average level of conservation, since the role of trees is crucial for the maintenance of cash crops (tea, coffee, dates) and of crops used by farmers' families for self-consumption.

The FAO GIAHS programme seems to be potentially important at an international level for the preservation of different traditional agroforestry systems and forest management techniques. An inclusion in the GIAHS programme does not have the power itself of preserving the traditional features, but it can contribute to raising the awareness of these important systems, especially in future generations of farmers [69]. These "agricultural heritage systems", in fact, can represent examples of adaptability and resilience towards socio-economic and climate changes, both in developing and developed countries. The tendency of increasing forested surfaces to contrast climate change, does not takes enough consideration of the problems of food supplies or pollution due to the long-range transport of food and materials, or recent studies demonstrating that the peak of carbon uptake for mature tropical forests has already been reached in the 1990s [70]. Agroforestry systems and homegardens can sequester sizeable quantities of C in plant biomass, in long-lasting wood products and in the soil, and the potential of agroforestry for CO_2 mitigation is today well recognized [71], even if agroforestry may involve practices that favor the emission of greenhouse gases (GHG), such as shifting cultivation, pasture maintenance by burning, paddy cultivation, N fertilization and animal production [72]. For example, conventional cattle breeding is a major source of GHG emissions, but traditional silvo-pastoral systems with cattle in South America are reported to be effective in carbon sequestration above- and belowground, with often higher values for traditional pastures with natural trees regarding carbon stock and carbon sequestration compared to pastures with planted trees [73]. At the local level, the shade effect of the trees is particularly important, with temperatures that can be 2–5 °C lower under the tree canopy compared to temperatures measured outside of the tree canopy [74], with positive effects on lower layer cultivations or on animal welfare and productions [75].

As the way of forests and agroforestry systems are managed have a high impact on soil, biodiversity, water quality and ecosystem services [76], forest-related traditional knowledge, as well as the valorization of local agroforestry systems, could represent important alternatives for global challenges [77].

The analysis also showed that there is a lack of a uniform approach in dealing with forest issues. Since forests and/or agroforestry systems proved to have a great importance and a multifunctional role in almost half of the sites in the GIAHS programme, it seems to be necessary to improve and standardize the description of the forest systems and of traditional forest management. The new guidelines for GIAHS proposals published in April 2020 (http://www.fao.org/3/ca8465en/ca8465en.pdf) seem to pay greater attention to the description of forest management plans and to the relation with protected areas or with local forest planning instruments. Moreover, it is mandatory for the applicants to include in the proposal a detailed land use map, specifying that its legend should also identify "forest types, species and management form (e.g., coppice, high stands, etc.)". This is a crucial innovation in the GIAHS programme, since detailed land use maps could establish a monitoring system based on land uses and carry out measurements and spatial analyses regarding forest types and management forms.

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Appendix A

Table A1. Importance of Forests and/or Agroforestry Systems for all the 59 Sites in the FAO GIAHS Program.

Country	Name of GIAHS Site	Forest and/or Agroforestry Systems Importance Score
Algeria	Ghout System (Oases of the Maghreb)	2
Bangladesh	Floating Garden Agricultural Practices	0
Brazil	Traditional Agricultural System in the Southern Espinaço Range, Minas Gerais	3
Chile	Chiloé Agriculture	1
China	Rice Fish culture	1
China	Wannian Traditional Rice Culture	1
China	Hani Rice Terraces	1
China	Dong's Rice Fish Duck System	1
China	Pu'er Traditional Tea Agrosystem	3
China	Aohan Dryland Farming System	0
China	Kuajishan Ancient Chinese Torreya	3
China	Urban Agriculture Heritage—Xuanhua Grape Garden	0
China	Jiaxian Traditional Chinese Date Gardens	2
China	Xinghua Duotian Agrosystem	3
China	Fuzhou Jasmine and Tea Culture System	2
China	Diebu Zhagana Agriculture-Forestry-Animal Husbandry Composite System	3
China	Zhejiang Huzhou Mulberry-dyke & Fish-pond System	0
China	Traditional Mulberry System in Xiajin's Ancient Yellow River Course	2
China	Rice Terraces in Southern Mountainous and Hilly Areas, China	1
Egypt	Dates production System in Siwa Oasis	3
India	Saffron Heritage of Kashmir	1
India	Koraput Traditional Agriculture	1
India	Kuttanad Below Sea Level Farming System	0
Islamic Republic of Iran	Qanat Irrigated Agricultural Heritage Systems, Kashan	0
Islamic Republic of Iran	Grape Production System in Jowzan Valley	0
Islamic Republic of Iran	Qanat–based Saffron Farming System in Gonabad	0
Italy	Olive groves of the slopes between Assisi and Spoleto	1
Italy	Soave Traditional Vineyards	1
Japan	Noto's Satoyama and Satoumi	2
Japan	Sado's Satoyama in Harmony with Japanese Crested Ibis	1
Japan	Managing Aso Grasslands for Sustainable Agriculture	1
Japan	Traditional Tea-grass Integrated System in Shizuoka	1
Japan	Kunisaki Peninsula Usa Integrated Forestry, Agriculture and Fisheries System	3

Table A1. *Cont.*

Country	Name of GIAHS Site	Forest and/or Agroforestry Systems Importance Score
Japan	Ayu of the Nagara River System	2
Japan	Minabe-Tanabe Ume System	2
Japan	Takachihogo-Shiibayama Mountainous Agriculture and Forestry System	3
Japan	Osaki Kodo's traditional water management system for sustainable paddy agriculture	3
Japan	Nishi-Awa Steep Slope Land Agriculture System	3
Japan	Traditional Wasabi Cultivation in Shizuoka	2
Kenya	Oldonyonokie/Olkeri Maasai Pastoralist Heritage	1
Mexico	Chinampas Agricultural System in Mexico City	2
Morocco	Oases System in Atlas Mountains (Oases of the Maghreb)	2
Morocco	Argan-based agro-sylvo-pastoral system within the area of Ait Souab-Ait Mansour	3
Peru	Andean Agriculture	0
Philippines	Ifugao Rice Terraces	2
Portugal	Barroso Agro-Silvo-Pastoral System	2
Korea	Traditional Gudeuljang Irrigated Rice Terraces in Cheongsando	2
Korea	Jeju Batdam Agricultural System	1
Korea	Traditional Hadong Tea Agrosystem in Hwagae-myeon	1
Korea	Geumsan Traditional Ginseng Agricultural System	2
Spain	Malaga Raisin Production System in Axarquia	1
Spain	Salt production system of Añana	2
Spain	The Agricultural System Ancient Olive Trees Territorio Sénia	1
Spain	The historical Irrigation System at L'horta de València	0
Sri Lanka	The Cascaded Tank-Village System in the Dry Zone of Sri Lanka	3
Tanzania	Engaresero Maasai Pastoralist Heritage Area	1
Tanzania	Shimbue Juu Kihamba Agroforestry Heritage Site	3
Tunisia	Gafsa Oases (Oases of the Maghreb)	3
United Arab Emirates	Al Ain and Liwa Historical Date Palm Oases	0

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