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Flora, life form characteristics, and plan for the promotion of biodiversity in South Korea's Globally Important Agricultural Heritage System, the traditional Gudeuljang irrigated rice terraces in Cheongsando

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Abstract: The objectives of this study were to analyze the biodiversity of the Traditional Gudeuljang Irrigated Rice Terraces in Cheongsando, South Korea's representative GIAHS (Globally Important Agricultural Heritage System) site, with reference to position and land-use features, and to develop a plan to promote agricultural biodiversity in the region. We confirmed approximately 54,000 m² of Gudeuljang paddy fields by an on-site survey. Of the Traditional Gudeuljang Irrigated Rice Terraces confirmed by on-site inspection, our survey showed that approximately 24,000 m² are currently being used as paddy fields, approximately 15,000 m² are being used as dry fields, and approximately 14,000 m² are fallow. In terms of other non-agricultural land use, there was grassland, including graveyards; artificial arboreal land, such as orchards, rivers and wetlands, and man-made facilities, such as roads and residences. We also confirmed that the Traditional Gudeuljang Irrigated Rice Terraces had higher plant species diversity than conventional terraced rice paddies, and there was a difference in life form characteristics between the two types. Although the superficial topsoil structure is the same for the Traditional Gudeuljang Irrigated Rice Terraces (TGIRTs) and conventional terraced rice paddies, it is thought that the differences in the subsurface structure of the TGIRTs contribute greatly to species and habitat diversity. However, the TGIRTs in Cheongsando are facing degeneration, due to damage and reduction in agricultural activity. The main cause is the reduction in the number of farming households due to an aging population in Cheongsando. In order to address this problem, we proposed a management plan, related to fallow paddy fields in South Korea, to initiate voluntary activities in the TGIRTs.

Keywords: Globally Important Agricultural Heritage System; Rice terrace; Agricultural biodiversity; Topsoil structure; Gudeuljang

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Introduction

In agricultural ecosystems, biodiversity provides various goods and services (Ecosystem Assessment 2005). A large numbers of ground-based organisms, pollinators, and natural enemies of pests contribute to biodiversity, and these play major roles in preservation of agricultural ecosystems, protection of hydrological systems and carbon capture. When biodiversity supports an agricultural ecosystem in this manner, it can be called agricultural biodiversity, and it provides a broad range of goods and services, from supporting agricultural production to various products (Wood and Lenne 1999; CBD 2000; Cromwell et al. 2001).

The importance of agricultural biodiversity has only recently been acknowledged by the international community, and was first discussed internationally at the Conference of the Parties (COP) for the Convention on Biological Diversity (CBD) in 1996. Following that, at the CBD's COP in 2000, the agenda included a CBD program of work for agricultural biodiversity, acknowledging its importance in the preservation of the agricultural system, sustainable use, contributing to native and local communities, and in the life of farmers (Jarvis et al. 2010).

With the ongoing debate on agricultural biodiversity at an international policy level, there is an need to introduce systematic devices that treat agricultural biodiversity with importance and lead to the next step. For this reason, the United Nations Food and Agriculture Organization (FAO) established the Globally Important Agricultural Heritage Systems (GIAHS) program in 2002, to value and protect agricultural systems with rich landscapes, biodiversity and cultural significance. This was developed with respect to indigenous traditional agriculture and agricultural land use that has developed and formed over several centuries, adapting to the changing environment. In addition, this has created an opportunity for the term and concept of "agricultural heritage" to receive international attention.

A global agricultural heritage site can be defined according to FAO as a "land-use system or landscape, rich in biodiversity of international significance, that has evolved in coexistence with a society that has adapted it to the environment and the needs of that society for the sake of sustainable development". It also means a complex system comprising the agriculture, ecosystem, knowledge, technology, society, culture, and landscapes accumulated over several centuries by a community, as well as the interactions among them (Park et al. 2013). This concept includes the core factors of biodiversity, land-use systems, and landscape. In particular, biodiversity, within the concept of agricultural heritage, is not only important in the preservation of species in their natural state, but also in their preservation and evolution alongside human agricultural activities (Yoon and Choi 2012).

As of May 2017, 37 agricultural sites around the world had been designated as GIAHS sites. Most of these have unique agricultural features, such as mountainous terraced rice paddy systems; multiple cropping systems; below sea level farming systems; nomadic systems; ancient irrigation; soil and water management systems; complex multi-story gardens; seabed agricultural systems; and high-value grain and spice systems. In South Korea, there are 2 designated GIAHS sites, the TGIRTs in Cheongsando and the Jeju Batdam Agricultural System at Heukryongmanri.

The TGIRTs in Cheongsando were designated as the first South Korean GIAHS site. This is a unique agricultural system with origins distinct from anywhere else in the world. As the population of Cheongsando increased over time, the residents had to obtain land for farming to increase the production of edible grains despite the limited land availability. They started creating the TGIRTs in order to make arable land out of stone in excessively drained valleys, where rice farming was otherwise difficult. To make use of the limited land available for farming, a revolutionary irrigation/drainage system had to be conceived. To this end, *Gudeuljang* (These are broad, rectangular stones used in a traditional underfloor home-heating system, which can be laid under the floor and directly heated to make the room warmer) were placed beneath the soil surface in cultivated areas. This was performed in an *ondol* (A traditional structure, in which Gudeuljang are laid under the floor and when a fire is lit beneath the Gudeuljang, they heat up, warming the room) structure, in which the Gudeuljang are stacked in evenly-spaced stone columns below the surface, resulting in an agricultural expansion strategy suited to the natural environmental conditions in Cheongsando, where there is a lack of soil and many rocks. These unique underground structures, not only allowed the TGIRTs to have 2-tiered irrigation and drainage systems, but also enabled the use of arable land as either rice paddies or dry fields. In addition, when water was abundant, they could act as reservoirs, trapping water and preventing crop damage by stopping the cold water from mountainous areas from flowing directly onto farmland (Cho et al. 2012). These characteristics combine to create a system of high preservation value, due to the promotion of biodiversity on limited land, maintenance of livelihoods via increased production, continuation of a traditional agricultural method, the historical and cultural values associated with the TGIRTs production, and the complex landscapes produced by terraced farmland.

It has been determined that the agricultural expansion strategy of creating the TGIRTs on low productivity land has an important ecological function, insofar as it provides new habitats for organisms to live and promotes biodiversity. Furthermore, unlike regular arable systems, the TGIRTs have an underground structure resulting in environmental variability in characteristics such as humidity, temperature, and wind, and enhanced agricultural biodiversity. Plants are sensitive to humidity, nutrient availability, metabolism, and photo-environment, so there is a need to investigate the differences between the TGIRTs and regular arable land in terms of plant species diversity, species composition, and growth characteristics.

In this study, we examined the following hypotheses. First, although fewer flora were observed in the Traditional Gudeuljang Irrigated Rice Terraces than in the forest periphery, there was more flora in the TGIRTs observed than in the Rice-terraces Paddy-fields or in the village. Second, although the superficial topsoil structure is the same for the continuous TGIRTs and conventional terraced rice paddies, the characteristics of the life forms and the composition of plant species that in the TGIRTs and in the Rice-terraces Paddy-field would be different.

The purpose of this study was to verify these hypotheses based on a detailed location and vascular flora survey of the TGIRTs representing the Globally Important Agricultural Heritage System in Republic of Korea. Furthermore, the study sought to find ways to improve the value and maintenance of the TGIRT.

1 Methodology

1.1 Study site and scope

According to the GIAHS website, Cheongsando is an island in Wando County, located 19.2km south of Wando-eup in Wando-gun, Jeollanam-do, South Korea, at latitude 37°11′N,

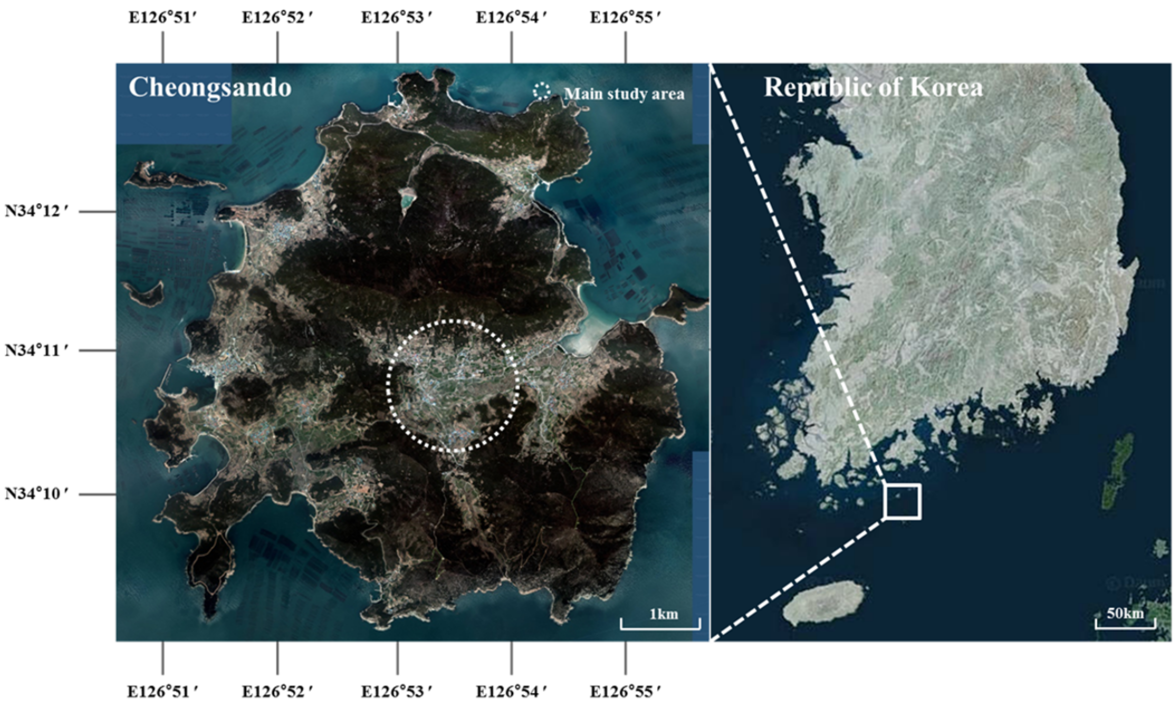

Figure 1 Maps of the study site on a national scale (Source of background map: http://map.daum.net/).

longitude 126°53′E (Figure 1). The island is composed of 5 inhabited and 9 uninhabited islets. The island has a basin in its center with an east-west orientation, and is composed of mountainous terrain with an altitude below 400m and a north-south orientation. With a total area of 42.7 km², it consists of 23 administrative zones, 13 legal zones, and 24 natural communities. As a mixed fishing and agricultural region, it is presently home to 2332 people in 1234 households. Until the mid-to-late twentieth century, the predominant industry was rice-based farming culture rather than fishing, but since the 2000s, fish farming has been increasing and rice farming has been in decline. Of Cheongsando's area, 71% is forested, 12.3% is paddy fields, and 8.9% is dry fields; the basin and gently sloping regions are mostly utilized for the TGIRTs, the terraced paddy fields, and the production of various other agricultural products.

Cho et al. (2012) investigated the distribution of the TGIRTs in Cheongsando and we used these results to determine our study region. Accordingly, we selected the whole region of Buheung-ri, Yangjung-ri, Sangdong-ri, and Cheonggye-ri, which were predicted to have high concentrations of the TGIRTs. Although there is no academic consensus on the definition of the TGIRTs, we defined them according to the criteria of Cho et al. (2012), i.e. paddy fields using the Gudeuljang stacked in an *ondol* structure.

1.2 Survey methods and analysis

1.2.1 The distribution of TGIRTs and surrounding land use

We performed a survey to ascertain the distribution of TGIRTs and the surrounding land use, in our study area. First, we interviewed the heads of the 23 villages in Cheongsando, giving us an indication of the locations of the TGIRTs. Second, based on by this testimony, we performed on-site surveys to confirm where the subterranean structures characteristic of the TGIRTs, such as stonework and water channels, could be observed. Third, in order to characterize land use surrounding the identified the TGIRTs, we performed satellite artificial imaging analysis followed by on-site confirmation of the locations of surrounding conventional paddy fields, dry fields, fallow ground, orchards, and villages. The survey was conducted between April and May in 2014, and the survey results were compiled using Arcmap GIS (3.3) into a 1:5,000 topographic map.

1.2.2 Vascular flora survey

To examine differences in flora among the land use types, we selected4 land use types as research sites: fully maintained TGIRTs, the Rice-terraces Paddy-field, forest periphery, and village. A total of 3 regions were selected and vascular flora were surveyed in each land use type. The survey was undertaken along accessible routes; however, the interior of farmland was excluded from the survey. We surveyed approximately 1 linear km in each land use type, recording all plants within sight within 5 m of either side of the path of travel. There were no major differences in the surveyed area among land use types. The survey routes were mostly selected to include high diversity environments, such as near water, where many species of plants are predicted to grow, as well as somewhat dry slopes. The survey and identification were conducted between April and May 2014.

For plant identification we followed the Korea Biodiversity Information System (Korea National Arboretum 2009) and the Engler classification system (Melchior 1964). As far as possible, identification was performed on-site; however, plants that could not be identified were collected for identification based on Lee (2003) and Hong et al. (1987). For naturalized plants, considered as the 321 groups, as classified by Lee et al. (2011), we calculated the naturalization rate (NR) as the total number of naturalized plant species divided by the total number of plant species that appeared in the study site (Numata 1975). For the life forms of the surveyed plants, we applied the methods of Raunkiaer (1934) and Numata (1970) to domestic plant species, and classified them by dormancy, radicoid form, disseminule form, and growth form, following Lee (1996). Figure 2 shows the survey route for each region and the associated land use classifications.

For statistical analysis, we conducted a Spearman correlation analysis and used non-parametric Kruskal-wallis tests to determine the statistical significance of survey results by each land use type.

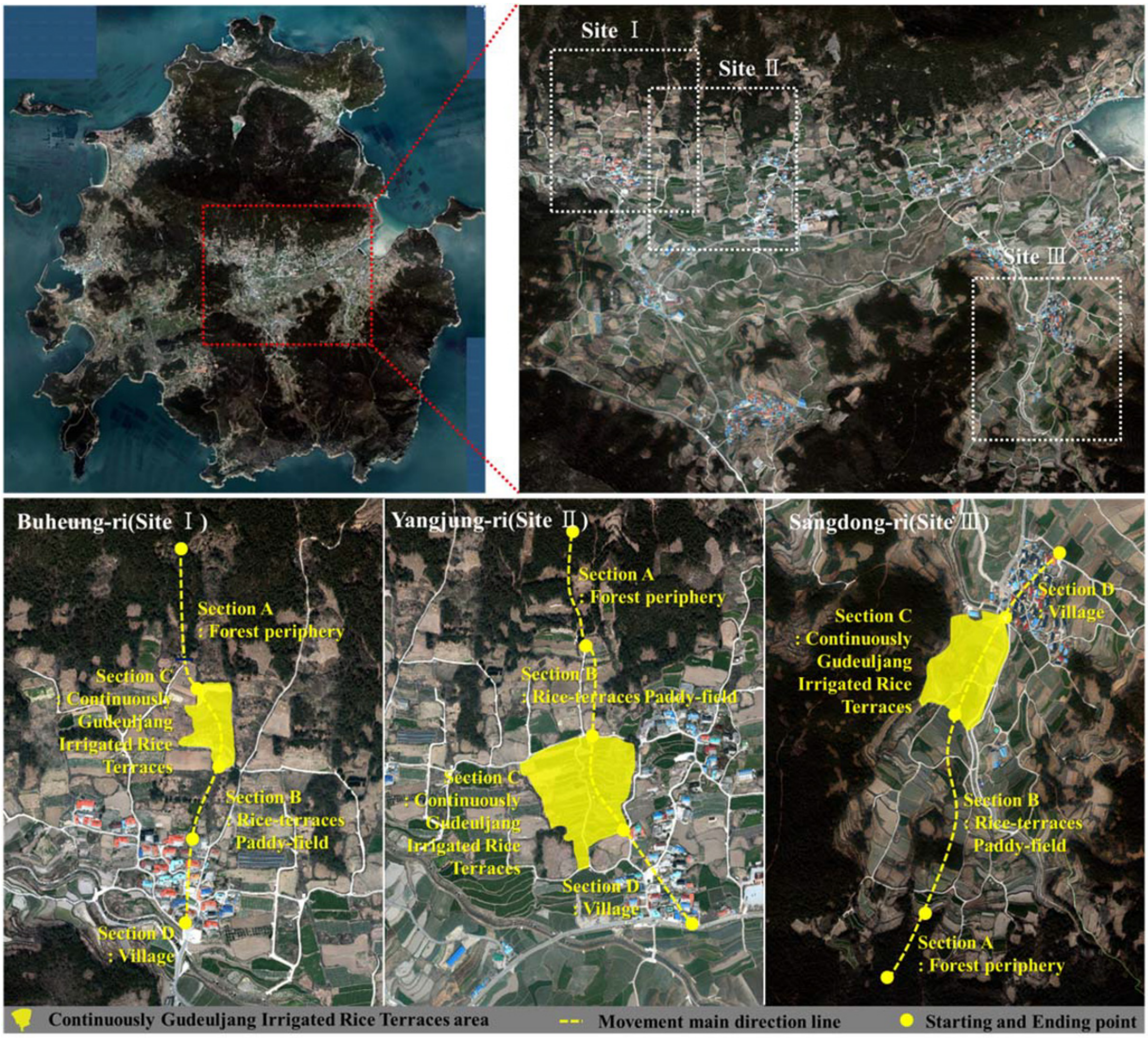

Figure 2 Maps of regional surveys and land use type (Source of background map: http://map.daum.net/).

1.2.3 Management systems and human and social aspects

We conducted a review of human and social aspects of the TGIRTs in Cheongsando, and systems for their preservation and management. From a human social perspective, we ascertained the current state and causes of the degeneration of TGIRTs, and proposed plans to improve these.

2 Results and Discussions

2.1 Structural understanding of the TGIRTs

Generally, the TGIRTs have a similar external appearance to conventional terraced rice paddies, but they have several differences based on their internal structure. First, conventional rice paddies are mostly found in coastal regions and continental mountainous regions in South Korea, but the TGIRTs have been discovered only in Cheongsando. In addition, in the terraced rice paddies the irrigation and drainage water flows above ground, and the foundations are built from a mixture of mud and rock. However, in the TGIRTs, the irrigation and drainage water flows both above and below the surface, and the foundations are made mostly of large stones (the Gudeuljang). Table 1 shows a comparison between the general features of conventional terraced rice paddies and the TGIRTs.

The greatest difference between the TGIRTs and conventional terraced rice paddies is the

Table 1 Comparison of the characteristics of conventional terraced rice paddies and the Traditional Gudeuljang Irrigated Rice Terraces in South Korea (Source: modified from Cho et al. (2012))

Division	Rice-terraces Paddy-field	The Traditional Gudeuljang Irrigated Rice Terraces
Distribution	In and around Mt. Jiri, In Sansheong-gun, Hamyang-gun, In the southern coastal area, In other mountainous inland areas	Cheongsando, Distribution unknown in other regions'
Location	In mountainous areas, such as restricted areas or slopes	In mountainous areas, such as restricted areas or slopes
Shape	Terraced shape, Drainage via surface layer, A foundation built of dirt and stone	Terraced shape, Drainage via surface layer and underground, A foundation built of a big stone (Gudeuljang)
Underground structure	Mainly soil, No underground structure	Mainly Gudeuljang stone, Stone pillars and floor heating structure
Photo		

subterranean structure. The TGIRTs are made up of 4 core structures. The topsoil layer where crops grow has an average thickness of 20–30 cm and is called "witbokgeul" in the local dialect. The layer below the topsoil, the mixed soil layer, is called "mitbokgeul" in the local dialect, and is a 20–30 cm layer made up of mixed mud and small stones; it prevents the loss of irrigation water. The next layer down comprises stacked stones, 20–50 cm across, and usually has a thickness of 70–300 cm. There are ducts intermittently located in between the lower stone stacks, which are made up of the Gudeuljang and stone pillars 50-200 cm in height. The ducts are square subterranean culverts, with sides of 30–50 cm. Figure 3 is a three dimensional drawing that displays the structure of the TGIRTs.

2.2 The distribution of TGIRTs distribution and the state of surrounding land use

We surveyed approximately 600,000 m^2 of the potential TGIRTs, identified by testimony, of which 240,000 m^2 were located in Buheung-ri, 170,000 m^2 in Yangjung-ri, 130,000 m^2 in Sangdong-ri, and 60,000 m^2 in Cheonggye-ri. Of these, approximately 54,000 m^2 of TGIRTs were confirmed on-site by the survey, with 29,000 m^2 in Buheung-ri, 11,000 m^2 in Yangjung-ri, and 14,000 m^2 in Sangdong-ri. The TGIRTs were mostly located around the valley area in the northwest of Buheung-ri, and around the hydrological system joining the valley, river, and coast in the southeast of Sangdong-ri. Figure 4 displays the distribution of the potential TGIRTs identified by testimony, and those confirmed on-site, in Buheung-ri, Yangjung-ri, Sangdong-ri, and Cheonggye-ri.

The region-specific features of the TGIRTs confirmed by on-site inspection were as follows. In Buheung-ri, there is a village in the hilly areas located all along the mountain ridge in the north and west, and the TGIRTs are distributed along the nearby valley. The TGIRTs located in upstream areas are created in the classic style of TGIRTs. The diameter of the stones used in the stone walls was over 1 m, differing from the diameter of the stones used on the stone walls in other areas. According to the testimony of the residents, the TGIRTs in the Yangjung-ri region were created later than those in Buheung-ri and Sangdong-ri, suggesting that the creation of the TGIRTs continued until relatively recently. In addition, the slope is shallower than in other regions, and thus the height of the stone stacks was lower, and the ducts could be constructed relatively deeply. Sangdong-ri is a region where the TGIRTs have been created since around the time Cheongsando was first settled, and

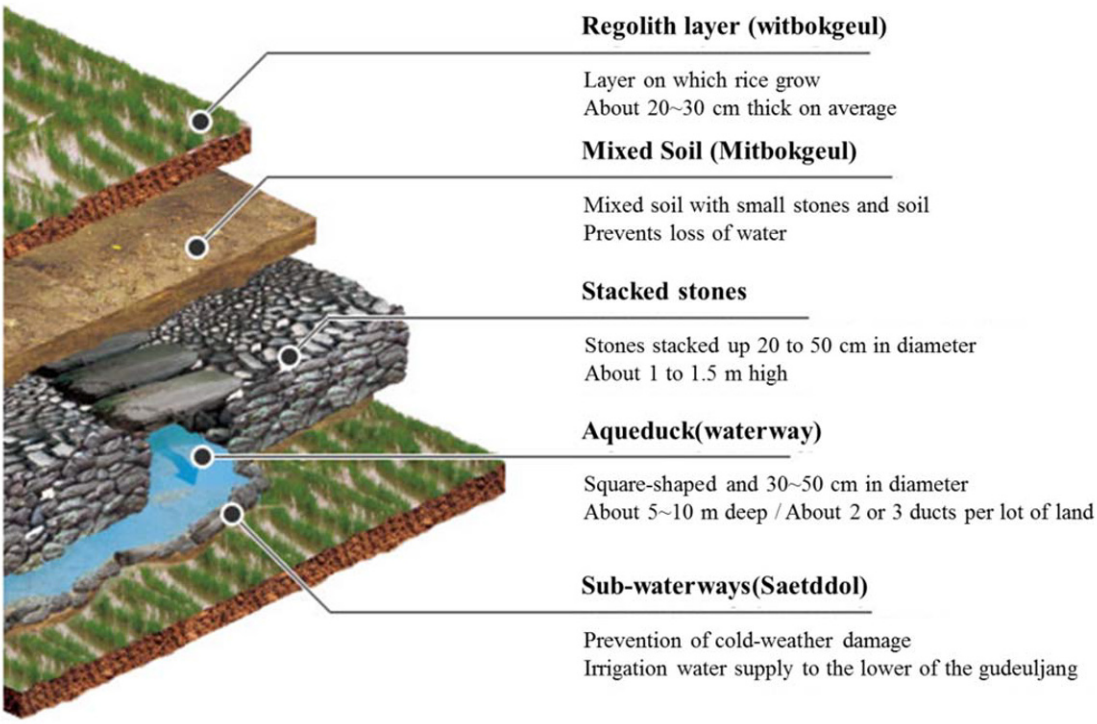

Figure 3 Layers of the Traditional Gudeuljang Irrigated Rice Terraces (Image source: Wondo County 2013).

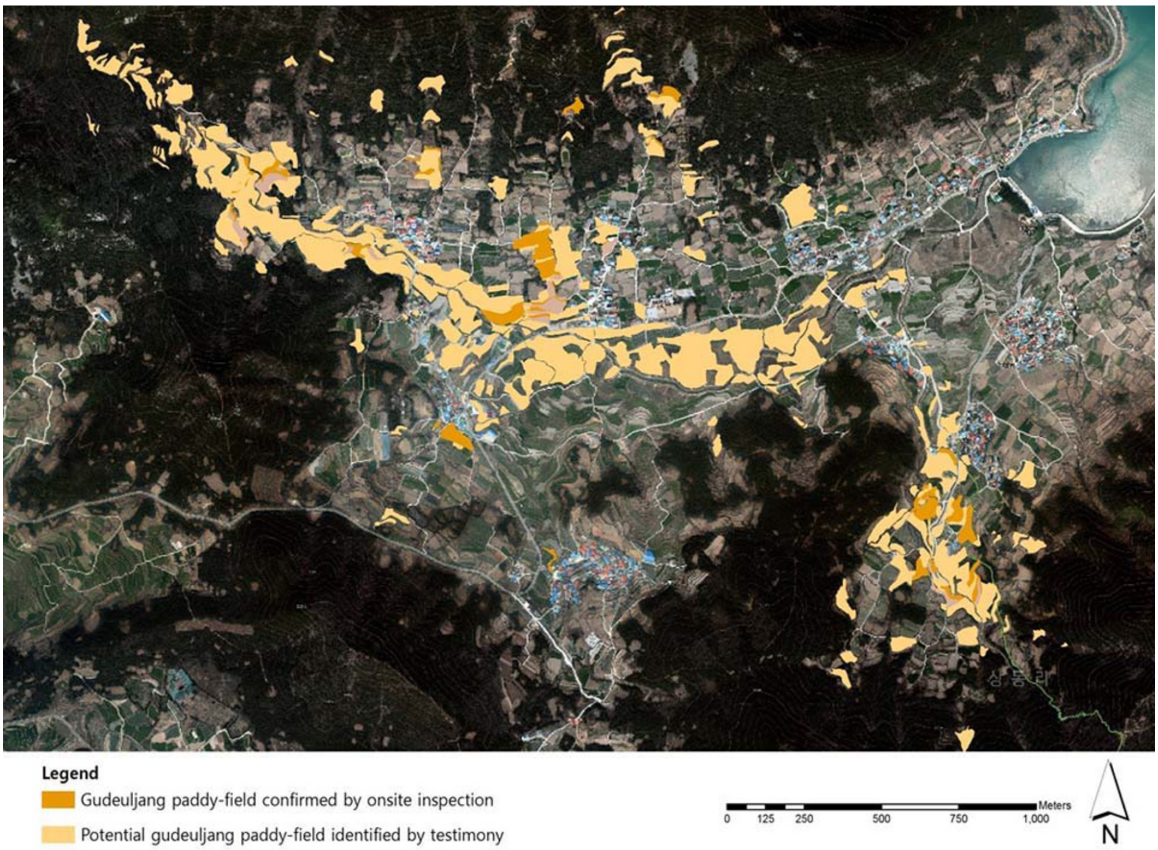

Figure 4 A map showing the potential Traditional Gudeuljang Irrigated Rice Terraces identified by testimony, and those confirmed by on-site inspection.

these were created between the ridge and the valley located in the south. They can be distinguished from the TGIRTs in other regions because there are at least 2 ducts, which have relatively large diameters. According to the testimony of the residents, many of the TGIRTs were damaged by river repair works in the early 2000s.

Surveys of land use in Buheung-ri, Yangjung-ri, Sangdong-ri, and Cheonggye-ri, where the TGIRTs are mostly distributed, showed that these were more often used as dry fields than as paddy fields. Dry fields made up 1,037,000 m^2, paddy fields made up 434,000 m^2, and fallow ground made up 351,000 m^2 of the total area identified as potential TGIRTs. Of the TGIRTs confirmed by on-site inspection, our survey showed that approximately 24,000 m^2 (14,000 m^2 in Buheung-ri, and 10,000 m^2 in Sangdong-ri) of the TGIRTs are currently being used as paddy fields, and approximately 15,000 m^2 (,000 m^2 in Buheung-ri, 4000 m^2 in Yangjung-ri, and 2000 m^2 in Sangdong-ri) of the TGIRT are being used as dry fields.

Conversely, the TGIRTs currently in a fallow state were found to have an area of approximately 14,000 m^2 (5,000 m^2 in Buheung-ri, 7000 m^2 in Yangjung-ri, and 2000 m^2 in Sangdong-ri). In terms of other non-agricultural land use, there was 142,000 m^2 of grassland, including graveyards, 49,000 m^2 of artificial arboreal land, such as orchards; 82,000 m^2 of rivers and wetlands, and 398,000 m^2 of man-made facilities, such as roads and residences. Figure 5 shows the state of land use surrounding the regions where the TGIRTs are mostly distributed.

2.3 Vascular plants

In our survey, the number of vascular plants across all regions was greatest in the forest periphery, followed by the continuous TGIRTs, then conventional terraced rice paddies, and finally villages. In particular, in the 3 regions of Buheung-ri, Yangjung-ri, and Sangdong-ri, there were more vascular plants in the continuous TGIRTs than in villages or conventional terraced rice paddies. Furthermore, regardless of the region, even when an integrated analysis was performed according to the type, there were more vascular plants in the continuous TGIRTs than in villages or conventional terraced rice paddies.

In the forest periphery, high proportions of plants belonged to the families Asteraceae (10.5%), Rosaceae (10.5%), and Fabaceae (8.5%), while in conventional terraced rice paddies, a high proportion belonged to Asteraceae (16.0%). In the continuous TGIRT, there were many plants belonging to Asteraceae (14.0%) and Poaceae (10.3%), with a higher proportion from Poaceae than in conventional terraced rice paddies. In villages, a high proportion of plants belonged to Asteraceae (21.3%).

There were 9 families, 13 genera, 11 species, 2 varieties, and 13 classification groups of vascular plants that were found exclusively in the continuous TGIRTs, and were absent from the forest periphery, conventional terraced rice paddies, and villages; these showed high numbers of R_4 (Clonal growth by stolons and struck roots) radicoid forms (46.1%) and D_4 (Having no special modification for dissemination) disseminule forms (84.6%). Furthermore, there were 22 families, 31 genera, 25 species, 5 varieties, 1 form, and 31 classification groups of vascular plants found in the continuous TGIRTs but not in conventional terraced rice paddies, and there were particularly high numbers of R_5 (Non-clonal growth; monophyte) radicoid forms (48.4%)and D_4 disseminule forms (61.3%). These include *Sedum sarmentosum* Bunge, *Dioscorea japonica* Thunb., *Pteris multifida* Poir., *Meehania urticifolia* (Miq.) Makino, *Metaplexis japonica* (Thunb.) Makino, *Vitis amurensis* Rupr., *Euonymus fortunei* var. *radicans* (Miq.) Rehder, and *Farfugium japonicum* (L.) Kitam., and the majority were characterized by the fact that they affix their roots to the foundation of the TGIRTs' stacked stone structure. Table 2 shows the results of the vascular plant survey for each study region.

2.4 Naturalized plants

The NR comprised 3.51% for forest periphery, 15.0% for conventional terraced rice paddies, 14.95% of continuous TGIRTs, and 16.0% for villages. The NR was similar for all land use types except for forest periphery, which receives little anthropic influence. Overall, *Erigeron annuus* (L.) Pers., *Sonchus asper* (L.) Hill, *Chenopodium album* L. var. *album*, and *Galinsoga ciliata* (Raf.) S.F.Blake appeared in most survey sites, while *Solanum*

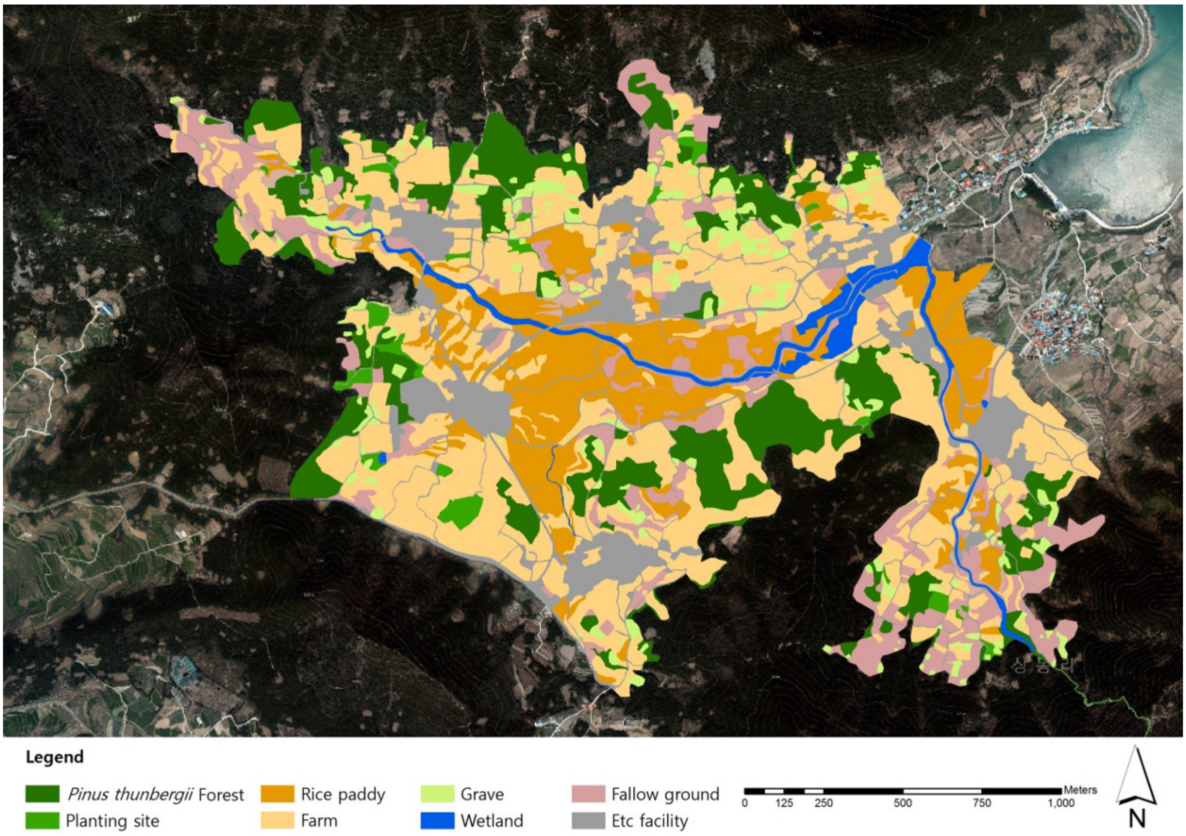

Figure 5 A map of land-use around the Traditional Gudeuljang Irrigated Rice Terraces.

Table 2 The flora of vascular plants in the survey districts

Division			Flora of vascular plants
Districts	Land-use type	Symbol	
Buheung-ri (Site Ⅰ)	Forest periphery	Ⅰ-A	43 families 71 genera 73 species9 varieties 3 forma 85 taxa
	Rice-terraces paddy-field	Ⅰ-B	31 families 48 genera 48 species4 varieties 52 taxa
	Gudeuljang Irrigated Rice Terraces	Ⅰ-C	38 families 59 genera 57 species 10 varieties 67 taxa
	Village	Ⅰ-D	21 families 30 genera 29 species1 varieties 30 taxa
Yangjung-ri (Site Ⅱ)	Forest periphery	Ⅱ-A	37 families 67 genera 65 species1 subspecies 13 varieties 2 forma 81 taxa
	Rice-terraces paddy-field	Ⅱ-B	35 families 51 genera 50 species 1 subspecies 5 varieties 56 taxa
	Gudeuljang Irrigated Rice Terraces	Ⅱ-C	32 families 59 genera 55 species 1 subspecies 11 varieties 67 taxa
	Village	Ⅱ-D	29 families 43 genera 40 species4 varieties 44 taxa
Sangdong-ri (Site Ⅲ)	Forest periphery	Ⅲ-A	43 families 67 genera 67 species1 subspecies 10 varieties 2 forma 80 taxa
	Rice-terraces paddy-field	Ⅲ-B	38 families 62 genera 57 species 1 subspecies 9 varieties 67 taxa
	Gudeuljang Irrigated Rice Terraces	Ⅲ-C	38 families 69 genera 65 species 1 subspecies 9 varieties 1 forma 76 taxa
	Village	Ⅲ-D	32 families 49 genera 48 species 4 varieties 52 taxa
All site total	Forest periphery	A	49 families 92 genera 96 species 1 subspecies 14 varieties 3 forma 114 taxa
	Rice-terraces addy-field	B	52 families 89 genera 86 species1 subspecies 13 varieties 100 taxa
	Gudeuljang Irrigated Rice Terraces	C	50 families 92 genera 91 species 1 subspecies 14 varieties 1 forma 107 taxa
	Village	D	41 families 67 genera 67 species 8 varieties 75 taxa

carolinense L., which has been designated an ecosystem-disrupting plant by the Ministry of Environment, was found in a conventional terraced rice paddy at Buheung-ri. *Erigeron annuus* (L.) Pers. and *Robinia pseudoacacia* L. were widespread in forest periphery areas. *Erigeron annuus* (L.) Pers., *Gnaphalium calviceps* Fernald, *Rumex crispus* L., *Sonchus asper* (L.) Hill, *Galinsoga ciliata* (Raf.) S.F.Blake, and *Chenopodium album* L. var. *album* were widespread in conventional terraced rice paddies (Table 3). In the continuous TGIRTs, *Erigeron annuus* (L.) Pers., *Conyza canadensis* (L.) Cronquist, *Bidens frondosa* L., *Rumex crispus* L., *Dactylis glomerata* L., *Sonchus asper* (L.) Hill and *Chenopodium album* L. var. *album* were widespread. In villages, *Conyza canadensis* (L.), *Phytolacca americana* L., *Bidens frondosa* L., *Galinsoga ciliata* (Raf.) S.F.Blake, and *Chenopodium album* L. var. *album* were widespread.

2.5 Life form characteristics

2.5.1 Dormant form

N (nanophanerophytes; 21.05%) types made up the highest proportion in forest periphery, with G (geophytes; 18.42%), H (hemicrytophytes; 17.54%), MM (macrophanerophytes; 15.79%), and M (mesophanerophytes; 14.04%) types showing relatively high proportions (Table 4). Th(w) (therophytes; 18.0%) types made up the highest proportion in conventional terraced rice paddies, with Th (therophytes; 17.0%), H(16.0%), and N (15.0%)types showing relatively high proportions. H (17.76%) types made up the highest proportion in the continuous TGIRTs, with Th(w) (16.82%) and Th (15.89%) types showing relatively high proportions. In villages, H, Th, and Th(w) types all had identical (17.33%), relatively high proportions.

In the case of forest periphery, there were more G, M, MM, and N types than in other land use types; conversely, there were fewer Th and Th(w) types. In the case of the T TGIRTs, there were more G types than in conventional terraced rice paddies, while there were fewer M types.

2.5.2 Radicoid form

In all land use types, R_5 (Non-clonal growth; monophyte) types made up the greatest proportion (forest periphery 56.14%, conventional terraced rice paddies 67.0%, continuous TGIRTs 56.07%, villages 56.0%) (Table 5).

In the case of forest periphery areas, there were more R_3 (Narrowest extent) types than in

Table 3 The flora of naturalized plants in the survey districts

Scientific name	Forest periphery	Rice-terraces Paddy-field	Gudeuljang Irrigated Rice Terraces	Village
Erigeron annuus (L.) Pers.	Appearance	Appearance	Appearance	Appearance
Senecio vulgaris L.	N/A	Appearance	Appearance	Appearance
Lepidium apetalum Willd.	N/A	Appearance	Appearance	N/A
Fallopia dumetorum (L.) Holub	N/A	Appearance	Appearance	N/A
Solanum carolinense L.	N/A	N/A	N/A	N/A
Rumex obtusifolius L.	N/A	N/A	Appearance	Appearance
Helianthus tuberosus L.	N/A	N/A	N/A	Appearance
Conyza canadensis (L.) Cronquist	N/A	Appearance	Appearance	Appearance
Bidens frondosa L.	N/A	Appearance	Appearance	Appearance
Phytolacca americana L.	N/A	Appearance	Appearance	N/A
Sonchus oleraceus L.	N/A	N/A	N/A	Appearance
Taraxacum officinale Weber	N/A	N/A	N/A	Appearance
Gnaphalium calviceps Fernald	N/A	Appearance	Appearance	N/A
Rumex crispus L.	N/A	Appearance	Appearance	Appearance
Robinia pseudoacacia L.	Appearance	N/A	Appearance	N/A
Dactylis glomerata L.	Appearance	Appearance	Appearance	N/A
Veronica persica Poir.	N/A	Appearance	Appearance	N/A
Sonchus asper (L.) Hill	Appearance	Appearance	Appearance	Appearance
Galinsoga ciliata (Raf.) S.F.Blake	N/A	Appearance	Appearance	Appearance
Lolium perenne L.	N/A	Appearance	N/A	N/A
Chenopodium album L.	N/A	Appearance	Appearance	Appearance

Table 4 A table of the frequency of the Dormant Forms (DoF)

DoF	Forest periphery (%)	Paddy-field (%)		Village (%)
		Rice terraces	Gudeuljang	
Ch	5.26	7.00	6.54	8.00
E	0.00	1.00	0.93	1.33
G	18.42	9.00	13.08	13.33
H	17.54	16.00	17.76	17.33
HH(Th)	0.00	0.00	1.87%	1.33
M	14.04	8.00	4.67	4.00
MM	15.79	9.00	9.35	10.67
N	21.05	15.00	13.08	9.33
Th	5.26	17.00	15.89	17.33
Th(w)	2.63	18.00	16.82	17.33

Notes: Ch: chamaephytes; E: epiphytes; G: geophytes; H: hemicrytophytes; HH(Th): therophytic aquatic; M: mesophanerophytes; MM: macrophanerophytes; N: nanophanerophytes; Th: therophytes; Th(w): therophytes (winter annual)

Table 5 A table of the frequency of the Radicoid Forms (RF)

RF	Forest periphery (%)	Paddy-field (%)		Village (%)
		Rice terraces	Gudeuljang	
$R_{(t)}$	0.88	1.00	0.00	
$R_{1\text{-}2}$	1.75	2.00	1.87	
$R_{2\text{-}3}$	7.02	5.00	4.67	9.33
R_3	24.56	11.00	15.89	12.00
$R_{3(b)}$	0.00	0.00	0.00	1.33
$R_{3(o)}$	0.00	1.00	0.93	1.33
$R_{3(s)}$	3.51	3.00	1.87	0.00
$R_{3(t)}$	0.00	0.00	0.00	1.33
$R_{3(v)}$	0.00	1.00	1.87	4.00
R_4	3.51	6.00	12.15	9.33
R_5	56.14	67.00	56.07	56.00
$R_{5(s)}$	2.63	2.00	3.74	2.67
$R_{5(c)}$	0.00	1.00	0.93	0.00

Notes: R_1: Widest extent of rhizomatous growth; R_2: Moderate extent; R_3: Narrowest extent; R_4: Clonal growth by stolons and struck roots; R_5: Non-clonal growth (monophyte); $R_{(b)}$: Scaly bulb; $R_{(c)}$: Bulb; $R_{(t)}$: Tuber; $R_{(r)}$: Tuberous root; $R_{(s)}$: Fleshy root; $R_{(o)}$: Oblique rhizome; $R_{(v)}$: Vertical rhizome.

other land use types. For the continuous TGIRTs, there was a higher proportion of R_3 types than in conventional terraced paddy fields, while there was a lower proportion of R_5 types.

2.5.3 Disseminule form

In forest periphery areas, D_4 (Having no special modification for dissemination) types made up the highest proportion (31.58%), and there was a relatively high, identical proportion of D_1 (Disseminated widely by wind and water) and D_2 (Disseminated attaching to or eaten by animals and man) types (26.32%). In conventional terraced rice paddies, D_4 types made up the highest proportion (18.0%), and there was a relatively high proportion of D_1 types (27.0%). In the continuous TGIRTs, D_4 types made up the highest proportion (40.19%), and there was a relatively high proportion of D_1 types (23.36%). In villages, D_1 types made up the highest proportion (33.33%), and there was a relatively high proportion of D_4 types (30.67%).

In the case of forest periphery areas, there were more D_2 types than in other land use types. In villages, there were more D_1 types than in other land use types. In the continuous TGIRTs, there was a lower proportion of D_1 types than in conventional terraced rice paddies, while there was a higher proportion of D_4 types (Table 6).

2.5.4 Growth form

In all land use types, e (erect form) types made up the highest proportion (forest periphery 54.36%, conventional terraced rice paddies 33.0%, the continuous paddy fields 30.84%, villages 29.33%) (Table 7).

In the forest periphery there were more e types than in other land use types, while there were fewer pr types. In the case of the continuous paddy fields, there was a higher proportion of b-p (branched form and procumbent form) forms than in conventional terraced rice paddies, while there was a lower proportion of e-b (erect form and branched form) types.

2.6 Statistical significance

2.6.1 Correlation analysis

'Flora of vascular plants' had the highest correlation coefficient of 0.948 (Table 8). Therefore, statistically, more flora are observed from the village to the Rice-terraces Paddy-fields, to the TGIRTs, and to the forest periphery. Although fewer flora were observed in the TGIRTs than in the forest periphery, there was more flora in the TGIRTs observed than in the Rice-terraces Paddy-fields or in the village. Moreover, among 'dormant forms', 'G, H, M, MM, N types' had high correlation coefficients. Similar to the observed flora, this statistically means that the

Table 6 A table of the frequency of the Disseminul Forms (DiF)

DiF	Forest periphery (%)	Paddy-field (%)		Village (%)
		Rice terraces	Gudeuljang	
D_1	26.32	27.00	23.36	33.33
D_{1-2}	0.00	1.00	0.93	1.33
D_{1-4}	0.00	0.00%	1.87	0.00
D_2	26.32	19.00	16.82	14.67
D_{2-4}	8.77	8.00	6.54	8.00
D_3	5.26	7.00	6.54	6.67
D_{3-2}	0.00%	0.00	0.93	0.00
D_4	31.58%	36.00	40.19	30.67
D_{4-1}	0.88	1.00	1.87	2.67
D_{4-2}	0.88	1.00	0.93	1.33
D_{5-4}	0.00	0.00	0.00%	1.33%

Notes: D_1: Disseminated widely by wind and water; D_2: Disseminated attaching to or eaten by animals and man; D_3: Disseminated by mechanical propulsion of dehiscence of fruit; D_4: Having no special modification for dissemination; D_5: Not producing seeds; D_{a-b}: Both types of 'a' and 'b'.

Table 7 A table of the frequency of the Growth Forms (GF)

GF	Forest periphery (%)	Paddy-field (%)		Village (%)
		Rice terraces	Gudeuljang	
b	0.88	5.00	3.74	4.00
b-l	1.75	3.00	2.80	1.33
b-p	1.75	2.00	5.61	4.00
b-ps	0.88	1.00	1.87	2.67
e	54.39	33.00	30.84	29.33
e-b	4.39	4.00	1.87	2.67
l	13.16	16.00	14.02	17.33
l-b	3.51	5.00	4.67	4.00
p	0.88	2.00	2.80	1.33
p-b	0.00	0.00	1.87	0.00
p-l	1.75	2.00	1.87	2.67
p-ps	0.88	0.00	0.00	1.33
pr	3.51	7.00	5.61	8.00
ps	3.51	8.00	8.41	8.00
ps-b	0.88	1.00	0.00	0.00
r	0.00%	2.00%	2.80	5.33
t	7.89	9.00	11.21%	8.00

Notes: e: erect form; b: branched form; t: tussock form; l: climbing or liane form; p: procumbent form; r: rosette form; pr: partial-rosette form; ps: pseudo-rosette form.

aforementioned flora types are observed more often than those when moving from the village to the Rice-terraces Paddy-fields, to the TGIRTs, and to the forest periphery. In addition, similar trends were observed in 'R_3, $R_{3(b)}$, $R_{3(s)}$, R_5, $R_{5(s)}$ types' among 'radicoid forms', in 'D_1, D_2, D_{2-4}, D_4 types' among 'disseminule forms', and in 'e, e-b, l, t types' among 'growth types'.

2.6.2 Non-parametric test

Statistical significance ($p \leqslant 0.05$) was observed in the following: 'flora of vascular plants'; 'naturalized plants'; 'G, H, HH(Th), N, Th, Th(w) types' among 'dormant forms'; 'R_3, $R_{3(s)}$, R_5, $R_{5(s)}$ types' among 'radicoid forms'; 'D_{1-2}, D_2, D_{2-4} types' among 'disseminule forms'; and 'b-l, b-p, e, e-b, p-ps, pr, t types' among 'growth types' (Table 9). Therefore, statistically this means that the results of investigation of the aforementioned elements differed in each of the 4 land use types (village, Rice-terraces Paddy-field, TGIRTs, and forest periphery). Therefore, the number and characteristics of flora differ in each land use type.

2.7 Degeneration of the TGIRTs and plans for improvement

2.7.1 State and causes of degeneration

There is a high risk of damage or destruction of the stone stacks and duct structures that form the foundations of the TGIRTs, not only due to the long time that has passed since they were created, but also because they are located on slopes, and are affected by environmental changes, such as variable wind, temperature, and humidity, and the seasons. Apart from these natural factors, damage and destruction occurs due to artificial factors, such as irrigation canal repairs, farm road extensions, and river modification works. These causes of damage and destruction can be mitigated when continuous agricultural activity takes place together with maintenance and repair. However, with the present decline in the farming population in Cheongsando, agricultural use of the TGIRTs is also decreasing, and approximately 26% of the TGIRTs (14,000 m^2) are being neglected and lie fallow. As a result, there has been a decrease in the Gudeuljang paddy field maintenance and repair activities in Cheongsando, leading to accelerated damage and destruction.

The direct cause of this degeneration of the TGIRTs is thought to be the decrease in the number of agricultural households due to an aging and declining population. There is a concentration of villages in the center of Cheongsando, which is an island with a developed agricultural culture

Table 8 Results of Spearman's correlation between Land-use type

Data items		Flora	G	H	M	MM	N	R_3
Land-use type	Correlation Coefficient	-0.948**	-0.844**	-0.878**	-0.683*	-0.716**	-0.958**	-0.958**
	Sig. (2-tailed)	0.000	0.001	0.000	0.014	0.009	0.000	0.000
	N	12	12	12	12	12	12	12
Data items		$R_{3(b)}$	$R_{3(s)}$	R_5	$R_{5(s)}$	D_1	D_2	$D_{2\text{-}4}$
Land-use type	Correlation Coefficient	0.600*	-.841**	-0.876**	-0.770**	-0.639*	-0.800**	-0.816**
	Sig. (2-tailed)	0.039	0.001	0.000	0.003	0.025	.002	0.001
	N	12	12	12	12	12	12	12
Data items		D_4	e	e-b	l	t		
Land-use type	Correlation Coefficient	-0.779**	-.844**	-0.617*	-.739**	-0.582*		
	Sig. (2-tailed)	0.003	0.001	0.032	0.006	0.047		
	N	12	12	12	12	12		

Notes: **: Correlation is significant at the 0.01 level (2-tailed), *: Correlation is significant at the 0.05 level (2-tailed)

Table 9 Results of Kruskal Wallis Test (nonparametric test)

Data items	Flora	Naturalized plants	G	H	HH(Th)	N	Th	Th(w)
Chi-square	9.904	8.970	9.070	8.715	8.463	9.186	8.653	8.495
df	3	3	3	3	3	3	3	3
Asymp. Sig.	0.019	0.030	0.028	.033	0.037	0.027	0.034	0.037
Data items	R_3	$R_{3(s)}$	R_5	$R_{5(s)}$	$D_{1\text{-}2}$	D_2	$D_{2\text{-}4}$	b-l
Chi-square	10.152	9.091	9.070	8.603	8.486	8.929	7.882	9.054
df	3	3	3	3	3	3	3	3
Asymp. Sig.	0.017	0.028	0.028	0.035	0.037	0.030	0.049	0.029
Data items	b-p	e	e-b	p-ps	pr	t		
Chi-square	8.278	9.495	8.541	8.250	8.280	8.223		
df	3	3	3	3	3	3		
Asymp. Sig.	0.041	0.023	0.036	0.041	0.041	0.042		

Note: The grouping criterion is land-use type

centered on rice-based farming and a representative mixed agricultural and fishing region in Wando-gun. Accordingly, the influx of young people from outside has been low. According to the statistical yearbook published in Wando-gun, in 2013, the elderly population (over 65 years old) in Cheongsando was over 1000, comprising more than 40% of the total population, and thereby it has become an 'elderly society' (Table 10). In addition, 20–50 year-olds comprised less than 25% of the population, and the death rate was 4 times higher than the birth rate. If the current situation continues, where immigration and emigration are similar it is predicted that the population supporting Cheongsando's main industry, agriculture, will decline rapidly. In fact, over the last 5 years, the number of agricultural households in Wando-gun, including Cheongsando, has decreased by approximately 1500, and the population involved in agriculture has decreased by approximately 3000 people (Table 11). Consequently, the area of arable land has decreased by about 300 ha for rice paddy fields and 300 ha for dry fields, while production of the major crop, rice, has decreased by approximately 6,000,000 tons. In the last 3 years the number of agricultural households in Cheongsando has decreased by about 40, indicating that a similar decreasing trend in agricultural activity is occurring, albeit on a different scale.

However, with Cheongsando being designated the first Cittaslow (slow city) in Asia in 2007 and a diverse tourist infrastructure being constructed, there is the opportunity for it to develop as a popular tourist destination. The number of tourists visiting Cheongsando has increased 4-fold in the last 5 years, from 10,000 people to 40,000 people, and there is an increasing demand for accommodation and dining facilities. We think that the development of the tourist industry in Cheongsando may gradually accelerate the decline in agricultural activity, and actively interfere with the maintenance and preservation of the TGIRTs.

2.7.2 Plans for improvement

Continuous agricultural activity in the TGIRTs is required to increase their biodiversity and to prevent the loss of associated traditional farming

Table 10 State of population in Cheongsando

Age	Total	Male	Female
0~4	52	18	34
5~9	59	30	29
10~14	70	32	38
15~19	87	54	33
20~24	86	56	30
25~29	90	53	37
30~34	99	53	46
35~39	93	50	43
40~44	118	78	40
45~49	136	78	58
50~54	216	120	96
55~59	209	109	100
60~64	192	103	89
65~69	188	89	99
70~74	318	116	202
75~79	265	93	172
80~84	173	52	121
Aged 85 and over	89	25	64
Birth	13	4	9
Death	54	32	22
Total	2540	1209	1331
Family: 1362; Population: Total, 2540, Male 1209, Female 1331; Population density: 60.5; Area (km^2): 41.95 Population per family people aged 65 and over: 1033.			

Note: Based year 2013, exclude foreigner.

Table 11 State of farming in Wando-gun, including Cheongsando

Year	Farm family (households)	Farmers (people)	Area (ha)		Rice yield (Mton)
			Rice paddy	Dry field	
2009	6746	14,226	3159	4730	12,214
2010	4847	10,553	3116	4605	10,992
2011	5236	11,496	3020	4378	10,882
2012	5195	11,235	3045	4513	6779
2013	5278	11,311	2824	4471	6770

Note: Based year 2013

practices. Rather than investing time and money to physically maintain and the repaired TGIRTs without agricultural activity, it is preferable that traditional farming is continuous practiced and passed down from generation to generation, and that maintenance and repair of the stacked stone structures and ducts is carried out naturally by the farmers. This is because, the TGIRTs structures must be fully functional for agricultural activity to be possible, and thus the maintenance and repairs required can only be clearly identified when agricultural activity is taking place.

In order to achieve this, we need an incentive plan to actively encourage participation in national systems for reclamation of fallow farmland, such that the Cheongsando residents can support agricultural activities in the TGIRTs that are currently fallow. Although the farming activities are not for subsistence purposes, it will be necessary to induce minimal farming activities. It is possible to utilize direct payment systems that have been implemented as part of a national policy, such as the "Conservation of Rice-income Subsidy System", the "Less Favored Area Subsidy System", and the "Conservation of Landscape Subsidy System". Such direct payment systems provide subsidies on the condition that they are used for the preservation of minimum function or agricultural activities in farming households that possess arable land, and are valuable in the reclamation of fallow farmland. Supporting the use of these systems by means of incentives should induce the residents to perform voluntary minimum cultivation activities. In fact, in Cheongsando, 382 households are participating in the "Conservation of Rice-income Subsidy System", 647 households are participating in the "Less Favored Area Subsidy System", and 32 households are participating in the "Conservation of Landscape Subsidy System" (based on data from August, 2014). For these systems to work, an interest in active participation is required from the local community such that they actively use diverse direct payment systems to reclaim fallow TGIRTs and maintain their structure and function. The details of each system are described in Table 12.

3 Conclusions and Proposals

The TGIRTs in Cheongsando were conceived to create farmland on slopes where agricultural activity is difficult, and to increase insufficient food production. The TGIRTs have a terraced form on slopes near the forest periphery, and this external form exists in several places around the world. However, the subterranean, internal form has a duct structure that uses Gudeuljang and stone columns, making this one of South Korea's unique agricultural methods with origins unlike anywhere else in the world.

The TGIRTs in Cheongsando are concentrated

Table 12 Fallow farmland related rice subsidy system in South Korea

Name of system	Aims and Subsidies
Conservation of rice-income subsidy system (Fixed-system)	Maintaining the shape and function of farmland through subsidies to farmers regardless of fallow or cultivated
Less favored area subsidy system	Providing farmers living in disadvantaged areas with low agricultural productivity with subsidies
Conservation of landscape subsidy system	Maintaining scenic landscapes by planting crops through subsidies to farmers, contributing to the urban-rural exchanges and the rural economy

in the valley in the northeast part of Buheung-ri, and around the hydrological system connecting the valley, river, and coast in the southeast of Sangdong-ri. The potential TGIRTs reported by residents were found to cover approximately 600,000 m² in our survey, and the TGIRTs confirmed by on-site inspections were found to cover approximately 54,000 m². Looking at the distribution characteristics of the TGIRTs by region, villages in Buheung-ri are generally located in the hilly areas below the ridge on the north and west sides, and the TGIRTs are distributed in the surrounding valleys. In Yangjung-ri, given that the TGIRTs were formed later than in Buheung-ri or Sangdong-ri, it is thought that construction went on until relatively recently. In the Sangdong-ri region, the TGIRTs haves been created approximately since people first lived in Cheongsando, and are located between the valley and the ridge on the south side.

Investigation of land use of the reported TGIRTs revealed that these comprised 1,037,000 m² of dry fields, 434,000 m² of paddy fields, and 351,000 m² of fallow land. Of the TGIRTs that were confirmed through on-site inspections, approximately 24,000 m² comprised paddy fields, 15,000 m² was used as dry fields, and approximately 14,000 m² was fallow. It is thought that the area of confirmed TGIRTs could be greater than that identified at present, if on-site measurements could be performed for the potential TGIRTs identified by testimony through continued investigations and the cooperation of the residents.

Looking at the state of vascular plants, we were able to find more of vascular plants in the continuous TGIRTs than in conventional terraced rice paddies for all regions and, when we performed an analysis by type, irrespective of region, we found the same trend. Moreover, there were 31 classification groups of vascular plant that were continous found in irrigated paddy fields, but were not found in conventional terraced rice paddies. These plants generally affixed their roots to the stacked stone structures of the TGIRTs. There was no major difference in NR (15%) between conventional terraced rice paddies and the continuous T TGIRTs. In the life form analysis of the dormant form, there was a higher proportion of G types in the continuous TGIRTs than conventional terraced rice paddies, while there were a lower proportion of M types. For radicoid form, there were a higher proportion of R_3 forms, while there was a relatively lower proportion of R_5 forms. In analysis of disseminule form, there was a relatively higher proportion of D_4 forms than in conventional terraced rice paddies, while there was a lower proportion of D_1 forms. In growth form, there was a higher proportion of b-p forms than in conventional terraced rice paddies, while there was a relatively lower proportion of e-b forms. Ultimately, we confirmed that the continuous TGIRTs had higher plant species diversity than conventional terraced rice paddies, and there was a difference in life form characteristics between the 2 types. Although the superficial topsoil structure is the same for the continuous TGIRTs and conventional terraced rice paddies, it is thought that the structural differences of the continuous TGIRTs contributes greatly to species and habitat diversity.

However, the TGIRTs in Cheongsando are facing degeneration, due to damage and the reduction in agricultural activity. Currently, about 26% of the TGIRTs (approximately 14,000 m²) are being neglected and lie fallow. This leads to a reduction in the maintenance and repair of TGIRTs, leading to damage and destruction. It is thought that the main cause is the reduction in the number of farming households due to an aging population in Cheongsando. In 2013, the elderly population in Cheongsando (over 65 years old) exceeded 1000 people, comprising more than 40% of the total population, making it an “elderly society”. The 20–50-year-old population was less than 25%, and the death rate was 2.5-fold higher than the birth rate. The number of agricultural households has decreased by 44 in the last 3 years. If there is no additional influx of young people the number of farming households in Cheongsando will decline rapidly, and the degeneration of the TGIRTs will be accelerated. In order to counteract this, there is a need for active participation in national direct payment systems related to fallow farmland, such as the “Conservation of Rice-income Subsidy System”, so that the Cheongsando residents can support farming activities on fallow TGIRTs themselves. In direct payment systems, national subsidies are paid on the condition that they are used by farming households in possession of farmland to maintain minimum agricultural activity or functions. Active interest and participation are required at the local community level in order to preserve the form and function of the TGIRTs.

The present study is particularly important because it is the first study to confirm the enhancement effects from Korea's TGIRTs on species and habitat diversity. The TGIRTs exist only in Cheongsando, Korea, and there is no comparable area. Therefore, basic data collection and pilot studies by Korean researchers are required. In this regard, the present study is well-timed and appropriate, with important results on plant habitat environments. However, since it is still an early-phase study, limitations could exist regarding the number and timing of investigations, and the items investigated. Nonetheless, the present study is expected to be a fundamental base that can confirm the potential of the Globally Important Agricultural Heritage System for biodiversity enhancement.

However, further studies are required to elucidate the differences in the habitats available to organisms. These studies could seek to add new study sites and to investigate the inorganic environment, for example seasonal differences between the continuous TGIRTs and conventional terraced rice paddies in humidity, temperature, air volume, wind speed, and sunlight. Nevertheless, in the present study we confirmed that the underground structure of the TGIRTs increases biodiversity, and that it also has a partial effect on the habitat available to organisms. Collectively, these study results indicate that the TGIRTs in Cheongsando have great importance as land use systems for “environmental adaptation” and “maintenance of biodiversity”, as indicated in the definition of global agricultural heritage.

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