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Vegetational characteristics of abandoned paddy terraces in comparison with natural and constructed wetlands

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자연습지 및 인공습지와의 비교를 통해 본 계단식 묵논습지의 식생 특성

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Abstract

To understand vegetational characteristics of abandoned paddy terraces (APTs), species composition and plant species richness of APTs were compared with those of other natural- and constructed wetlands (NWs and CWs, respectively). Based on frequency of major vegetational components, *Phragmites japonicus* was more common in APTs (23.9%) than NWs (10.8%) and CWs (10.8%), whereas *P. australis* was less frequent in APTs (18.3%) than NWs (43.1%) and CWs (35.4%). *Typha orientalis* was common only in APTs (19.7%), whereas *T. angustifolia* was relatively common in NWs (21.5%) and CWs (32.3%). In addition, some wetland obligate species such as *Leersia japonica*, *Oenanthe javanica,* and *Sium suave* were frequently found only in APTs. In particular, APTs showed higher plant species richness (6.3 ± 2.2 species/m^2) than NWs (4.9 ± 1.8 species/m^2) and CWs (3.9 ± 1.3 species/m^2). APTs exhibited not only their distinctive vegetational characteristics but also higher ecological value in terms of plant species richness. Further attention on APTs as valuable biotopes supporting diverse plant species and continuous effort for management and conservation are needed more.

Key words : abandoned paddy fields, artificial wetlands, plant species richness, species composition, vegetation

요 약

계단식 묵논습지의 식생 특성을 이해하기 위하여, 계단식 묵논습지의 식물종 구성 및 종풍부도 양상을 대상으로 자연습지 및 인공습지와의 비교연구를 수행하였다. 달뿌리풀은 자연습지(10.8%)나 인공습지(10.8%)에 비해 계단식 묵논습지(23.9%)에서 상대적으로 자주 관찰된 반면, 갈대는 계단식 묵논습지(18.3%) 보다는 자연습지(43.1%)나 인공습지(35.4%)에서 보다 높은 비율로 출현하였다. 부들의 경우 계단식 묵논습지(19.7%)에서만 높은 비율로 출현한 반면, 애기부들의 경우 자연습지(21.5%)와 인공습지(32.3%)에서 상대적으로 높은 비율을 보였다. 그와 더불어, 나도겨풀, 미나리, 그리고 개발나물과 같은 몇몇 습지 의존성 식물들의 경우 오직 계단식 묵논습지에서만 관찰되었다. 특히, 계단식 묵논습지(6.3 ± 2.2 종/m^2)는 자연습지(4.9 ± 1.8 종/m^2) 및 인공습지(3.9 ± 1.3 종/m^2)에 비해 상대적으로 높은 수준의 식물 종풍부도를 나타내었다. 즉, 계단식 묵논습지는 특유의 식생 특성을 나타내었을 뿐만 아니라 종풍부도 차원에서 보다 높은 수준의 생태적 가치를 보인 것이다. 비오톱으로서 계단식 묵논습지가 갖는 높은 생태적 가치에 대한 계속적인 관심과 더불어, 이를 유지관리하고 보전하기 위한 차원에서의 지속적인 노력이 필요할 것이다.

핵심용어 : 묵논, 식물종풍부도, 식생, 인공습지, 종구성

1. Introduction

Abandoned paddy terraces (hereafter APTs) indicate naturalized wetlands that were developed as paddy fields within mountainous areas and then abandoned owing to a poor accessibility and low economic value as farmlands (Katoh et al., 2009; Hong et al., 2012, 2019b). As a result of intensive agriculture particularly in Asian countries such as China, Japan, and Korea for a long period of time (Park et al., 2013; Qiu et al., 2014; Fukamachi, 2017), the number of APTs has been continuously increased (Nam et al., 2014; Yoo et al., 2018;

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Hong et al., 2019b). Recently, many researchers have been interested in APTs as valuable wetland ecosystems (Katoh et al., 2009; Park et al., 2013; Fukamachi, 2017; Hong et al, 2019b).

In general, APTs consist of several layers of wetland units on a slope as multi-cell wetland ecosystems (Hong and Kim, 2013a; Park et al., 2013). These multi-layers within APTs often exhibit various environmental conditions in terms of soil nutrients and water levels through naturalization, possibly influencing vegetational characteristics in APTs (Byun et al., 2008; Park et al., 2013; Hong et al., 2019b). In particular, heterogeneous environments of APTs can support diverse wetland- inhabiting plant species (Nam et al., 2014; Hong et al., 2018a; Yoo et al., 2018).

Many studies have spotlighted high value of APTs in terms of ecological functions and economic potentials, particularly in Japan (Liyama et al., 2005; Fukamachi, 2017). In particular, some of these studies have reported on high biodiversity including rare species in APTs (Ikeda and Itoh, 2001; Uematsu et al., 2010). Similarly, a number of studies have recently addressed ecological importance of APTs as valuable biotopes supporting diverse and various types of plant species in Korea (Hong and Kim, 2013a; Park et al., 2013; Yoo et al., 2018; Hong et al., 2019b).

In Korea, although many studies have been reported on vegetational characteristics of APTs such as species composition and plant species richness so far (Byun et al., 2008; Park et al., 2013; Nam et al., 2014), these studies have been performed only in a small number of APTs. In addition, there has not been any comparative study focusing on vegetational characteristics of APTs yet. So, we firstly tried to compare vegetational characteristics of APTs with those of other types of wetlands. In order to understand vegetational characteristics of APTs as naturalized wetlands, APTs were compared with natural- and constructed wetlands (hereafter NWs and CWs, respectively). In particular, both species composition and plant species richness as vegetational characteristics were compared to verify the potential value of APTs as a biotope type. This study might provide meaningful information not only for a better understanding of vegetational characteristics of APTs but also for managing and conserving APTs as valuable biotopes.

2. Materials and Methods

2.1 Study sites

In order to compare vegetational characteristics of three different types of wetlands (APTs, NWs, and CWs), a total of 28 wetlands belonging to 22 administrative districts were selected as study sites (Table 1). The study sites were divided into three types of wetlands based on relevant literature (Byun et al., 2008; Hong et al., 2012, 2014; Min et al., 2012; Hong and Kim, 2013b; Park et al., 2013; Nam et al., 2014; Hong et al., 2019b), information by local governments, outer appearances, and private conversation with local people: APTs as naturalized marshes (n = 8), NWs (n = 12), and CWs (n = 8). Most wetlands were classified as a marsh type, in which herbaceous species are more frequent and dominant than tree species (Table 1).

In particular, we carefully selected APTs in which a continuous water inflow is guaranteed as naturalized wetlands. Otherwise, APTs can easily be transformed into upland-like fields through terrestrialization process (Lee et al., 2002; Yoo et al., 2018). APTs in Gokseong were reported as a habitat for an endangered dragonfly species, *Nannophya pygmaea* Rambur. (Yoon et al., 2011). An inhabitation of wetland moss species, *Sphagnum palustre* L. has also been exceptionally reported at APTs in Ansan (Hong and Kim, 2013a; Hong et al., 2019b). A near-threatened species, *Penthorum chinense* Pursh and a data-deficient species, *Sparganium japonicum* Rothert were recorded before at APTs in Dongducheon (Hong and Kim, 2013b).

At NWs in Goseong, a floating marsh mainly consisting of *Phragmites australis* (Cav.) Trin. ex Steud. was reported as a habitat for a couple of endangered plant species such as *Iris laevigata* Fisch., *Menyanthes trifoliata* L., and *Nymphaea tetragona* var. *minima* (Nakai) W.T. Lee (Kim et al., 2013; Hong et al., 2018a). *Sphagnum palustre* population in a *Ph. australis*-dominated fen was exceptionally reported at NWs in Hongcheon (Hong et al., 2019a).

Most CWs were constructed for purifying and supplying water. In contrast, CWs in Cheongju and Seongnam were developed as water-front places and also biotopes supplying diverse plant species including *S. palustre*.

2.2 Field survey

In order to estimate the frequency of each species for determining major vegetational components among wetland types, field surveys using a quadrat of 1 m^2 (1 m × 1 m) in area had been performed for five years (from 2009 to 2013). Prior to the surveys, the size of experimental quadrat was carefully determined by considering most vegetational characteristics of typical marshes such as herbaceous plants based on relevant literature (Oksanen, 1996; Pollock et al., 1998).

The surveys were performed based on different growing seasons of study sites from June at relatively high latitude and/or

Table 1. Geographical and investigative information of the study sites. Species number indicates the total number of plant species from each site.

Type	Administrative districts	Sub-type	Latitude	Longitude	Altitude (m)	Species number	Quadrat number	Survey date
APTs (n = 71)	Ansan	Marsh	37° 17'8.88"N	126° 55'20.35"E	83	41	13	Sep. 2012
	Boseong	Marsh	34° 48'25.06"N	127° 4'57.84"E	171	32	9	Sep. 2012
	Dongducheon	Marsh	37° 55'50.79"N	127° 2'1.62"E	119	27	7	Sep. 2013
	Gimcheon	Marsh	36° 1'32.41"N	128° 7'42.55"E	141	17	7	Aug. 2010
	Gokseong	Marsh	35° 15'53.38"N	127° 16'9.20"E	114	38	14	Jun. 2009
	Seoul (1)	Marsh	37° 39'21.00"N	126° 56'38.46"E	53	14	5	Aug. 2011
	Uljin	Marsh	36° 55'4.68"N	129° 24'36.98"E	56	23	10	Aug. 2012
	Yangju	Marsh	37° 51'26.04"N	127° 1'6.08"E	123	27	6	Sep. 2013
NWs (n = 65)	Changnyeong	Pond	35° 31'9.19"N	128° 24'6.58"E	15	14	5	Aug. 2010
	Goseong (1)	Littoral marsh	38° 28'19.72"N	128° 26'14.38"E	4	5	3	Jul. 2013
	Goseong (2)	Back marsh	38° 20'1.43"N	128° 31'13.60"E	5	24	11	Jul. 2013
	Goseong (3)	Floating marsh	38° 21'24.34"N	128° 30'13.37"E	5	14	5	Jul. 2013
	Goseong (4)	Floating marsh	38° 15'4.85"N	128° 33'41.05"E	8	13	4	Jul. 2013
	Gunsan	Pond	36° 0'31.88"N	126° 47'33.09"E	26	8	5	Jul. 2012
	Hapcheon	Floodplain	35° 32'5.82"N	128° 7'28.86"E	47	8	7	Aug. 2011
	Hongcheon	Fen	37° 50'30.61"N	128° 33'12.41"E	799	5	4	Jul. 2009
	Paju	Riparian marsh	37° 44'47.41"N	126° 46'54.53"E	9	7	8	Sep. 2009
	Seoul (2)	Riparian marsh	37° 31'6.56"N	126° 55'14.58"E	10	10	3	Sep. 2011
	Shinan	Pond	35° 2'20.62"N	126° 9'28.94"E	7	10	6	Jul. 2012
	Yangpyeong (1)	Riparian marsh	37° 38'25.57"N	127° 25'14.28"E	93	7	4	Jul. 2009
CWs (n = 65)	Cheongju	Marsh	36° 38'22.04"N	127° 36'11.73"E	288	23	13	Oct. 2013
	Daegu	Littoral marsh	35° 37'48.84"N	128° 29'4.28"E	68	15	12	Sep. 2009
	Gwangju	Pond	37° 28'23.55"N	127° 18'7.38"E	29	18	12	Oct. 2010
	Muan	Pond	34° 50'46.50"N	126° 24'40.20"E	5	9	5	Jul. 2012
	Pyeongchang	Marsh	37° 37'46.43"N	128° 29'21.24"E	648	11	5	Jul. 2013
	Seongnam	Marsh	37° 24'17.14"N	127° 8'29.67"E	75	33	9	Oct. 2013
	Seoul (3)	Marsh	37° 27'32.52"N	126° 57'23.89"E	146	12	4	Sep. 2011
	Yangpyeong (2)	Marsh	37° 29'38.56"N	127° 24'13.08"E	37	5	5	Sep. 2009

APTs = abandoned paddy terraces. NWs = natural wetlands. CWs = constructed wetlands.

altitude areas to October at relatively low latitude and/or altitude areas. A total of 201 experimental quadrats (APTs, n = 71; NWs, n = 65; CWs, n = 65) were randomly set on study sites with intervals at least 5 m between quadrats to avoid duplicating data particularly under homogeneous vegetational covers by monotypic occupation. The areas with an average water level of 〈 0 cm or 〉 200 cm were excluded from the survey to meet the purpose of the study.

In addition, the areas including endangered plant species such as *I. laevigata*, *M. trifoliata*, and *N. tetragona* var. *minima* in some NWs were also excluded from the survey to avoid any possible disturbance on these rare species. In order to compare major vegetational components of three different wetland types, areas that were mainly covered with wetland moss species (bryophytes) such as *Sphagnum* spp. and tree species such as *Salix* spp. and *Amorpha* spp. were also excluded from the field survey.

The taxonomic nomenclature designated by Lee (2003) and the Korean plant names index (KPNI, http://www.nature.go.kr) were used to identify all recorded plant species from the field survey. In particular, ranked species (over 10% in frequency) were determined based on frequency values of all species depending on wetland types to compare major vegetational components of three different wetland types. In addition, both total number of plant species (the number of all recorded plant species in the site) and plant species richness (the mean value of numbers of plant species per quadrat) were also compared among three different wetland types.

3. Results and Discussion

3.1 Plant species richness depending on wetland types

The number of plant species in APTs was twice of those in NWs and CWs. APTs had a total of 116 plant species accounting for about 72% of the total number of plant species from the study (Appendix 1). NWs and CWs had only 57 (about 35%) and 65 (about 40%) species, respectively. Most of all, APTs showed relatively high plant species richness (6.3 ± 2.2 species/m^2) than NWs (4.9 ± 1.8 species/m^2) and CWs (3.9 ± 1.3 species/m^2) (Fig. 1).

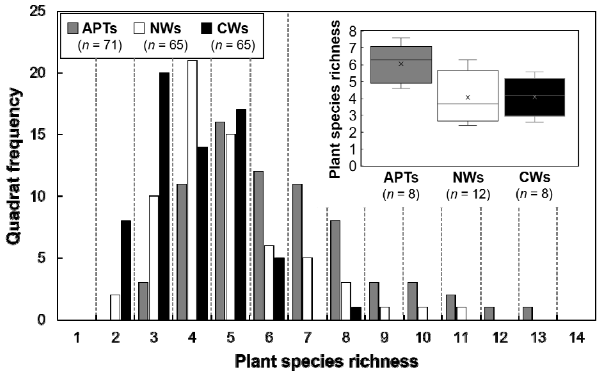

Fig. 1. The frequency distribution of plant species richness from three different wetland types. The box-plot graph in the figure was based on mean values of plant species richness from the study sites depending on wetland types. APTs = abandoned paddy terraces. NWs = natural wetlands. CWs = constructed wetlands.

Such diverse plant species in APTs could be attributed to environments of APTs such as chemistry and topography (Yun, 2007; Katoh et al., 2009; Hong et al., 2012). In particular, APTs have usually been developed in montane areas of low nutrients (Park et al., 2013; Kim et al., 2017). For example, Hong and Kim (2013a) reported an inhabitation of *S. palustre* in APTs. It may indicate low nutrients in the APTs because the *Sphagnum* species is particularly vulnerable to high nutrients (van Breemen, 1995; Hong and Kim, 2013c).

3.2 Major vegetational components depending on wetland types

A total number of 162 plant species were recorded throughout 28 wetlands (Appendix 1). Among the 162 plant species, 19 species were ranked as major vegetational components based on frequency of each species (over 10% in frequency) (Table 2). In addition, APTs also showed a higher value in the number of ranked species (〉 10% in frequency) than NWs and CWs. APTs had a total of 14 ranked species, whereas NWs (7 species) and CWs (10 species) had smaller numbers of ranked species (Table 2), possibly indicating a higher evenness in APTs than NWs and CWs.

Five species were commonly recorded with high frequency regardless of wetland types: 1. *Polygonum thunbergii* Siebold & Zucc. (39.8% in total), 2. *Ph. australis* (31.8%), 3. *Murdannia keisak* (Hassk.) Hand.-Mazz. (24.9%), 4. *Zizania latifolia* (Griseb.) Turcz. ex Stapf (21.9%), and 5. *Ph. japonicus* Steud. (14.9%) (Table 2). In particular, *Po. thunbergii* showed over 30% in frequency in all types of wetlands (Table 2), indicating that *Po. thunbergii* is a typical generalist (Kim et al., 2012; Park et al., 2013). Despite the fact that *Po. thunbergii* is a relatively short species when compared with other tall species such as *Ph. australis* and *Typha angustifolia*, such a wide distribution of *Po. thunbergii* regardless of wetland types could be attributed to its amphicarpy. It was reported that amphicarpy enables *Po. thunbergii* to produce two seed types depending on environmental conditions: aerial- and subterranean seeds (Choo et al., 2015; Kim et al., 2016). It was also been noted that *Po. thunbergii* can exhibit a rapid recovery after flooding disturbances, indicating highly-adaptive characteristic to its environment (Kim et al., 2012).

In addition, *M. keisak* also showed relatively high frequency in all types of wetlands particularly in natural wetlands (40.0%). *Murdannia keisak* is a small and short but widespread species in both the United States and Asian countries. It was noted that *M. keisak* usually exhibits phenotypic plasticity in biomass reallocation and a high reproductive capacity (Dunn and Sharitz, 1990). On the other hand, *Z. latifolia*, called as 'Asian wild rice', was also one of the most prevalent species in our study. It was reported that *Z. latifolia* often exhibits a superior capacity in vegetative reproduction and tolerance against flooding, enabling *Z. latifolia* to thrive under deep-water conditions (Hong et al., 2014; Byun et al., 2017). *Zizania latifoila* was also reported to contribute to the stabilization of floating mats with *Ph. australis* via conferring buoyancy on floating mats (Kim et al., 2013; Shin et al., 2015; Hong et al., 2018b).

Although *Ph. australis* was observed in all wetland types, *Ph. australis* was less frequent in APTs (18.3%) than NWs (43.1%) and CWs (35.4%)(Table 2). As the common name of *Ph. australis* (common reed) literally indicates, *Ph. australis* is one of the most prevalent macrophytes in wetland ecosystems showing a wide distribution (Hong et al., 2019a). Despite the fact that *Ph. australis* may occur in montane fens with extreme altitudes (Hong et al., 2019a), it seems that *Ph. australis* prefer lower areas rather than high-altitude areas such as APTs (Hong and Kim, 2013a; Kim et al., 2013; Hong et al., 2019a).

Phragmites japonicus was more common in APTs (23.9%) than NWs (10.8%) and CWs (10.8%)(Table 2). *Phragmites japonicus*, also called as 'runner reed' due to a characteristic

Table 2. Major vegetational components of APTs, NWs, and CWs based on frequency. Five species that were recorded in all wetland types were presented with bold letters. Numbers in brackets represent species ranks.

No. of quadrats / Scientific name	APTs (*n* = 71)	NWs (*n* = 65)	CWs (*n* = 65)	Total (*n* = 201)
Bidens frondosa	[8] 12 (16.9%)			
Echinochloa crus-galli			[4] 13 (20.0%)	[7] 23 (11.4%)
Echinochloa oryzoides			[9] 7 (10.8%)	
Glycine max subsp. *soja*	[11] 9 (12.7%)			
Humulus scandens	[9] 10 (14.1%)		[7] 8 (12.3%)	[7] 23 (11.4%)
Isachne globosa		[6] 10 (15.4%)		[10] 21 (10.4%)
Juncus effusus	[3] 15 (21.1%)			[7] 23 (11.4%)
Leersia japonica	[11] 9 (12.7%)			
Lythrum salicaria			[7] 8 (12.3%)	
Miscanthus sacchariflorus	[5] 13 (18.3%)			
Murdannia keisak	**[5] 13 (18.3%)**	**[3] 26 (40.0%)**	**[5] 11 (16.9%)**	**[3] 50 (24.9%)**
Oenanthe javanica	[9] 10 (14.1%)	-		
Phragmites australis	**[5] 13 (18.3%)**	**[2] 28 (43.1%)**	**[1] 23 (35.4%)**	**[2] 64 (31.8%)**
Phragmites japonicus	**[2] 17 (23.9%)**	**[7] 7 (10.8%)**	**[9] 7 (10.8%)**	**[6] 30 (14.9%)**
Polygonum thunbergii	**[1] 29 (40.8%)**	**[1] 31 (47.7%)**	**[3] 20 (30.8%)**	**[1] 80 (39.8%)**
Sium suave	[14] 8 (11.3%)			
Typha angustifolia		[5] 14 (21.5%)	[2] 21 (32.3%)	[5] 39 (19.4%)
Typha orientalis	[4] 14 (19.7%)			
Zizania latifolia	**[11] 9 (12.7%)**	**[4] 24 (36.9%)**	**[5] 11 (16.9%)**	**[4] 44 (21.9%)**
No. of wetlands	8	12	8	28
No. of ranked species (〉 10% in frequency)	14	7	10	10
Total No. of plant species	116	57	65	162

APTs = abandoned paddy terraces. NWs = natural wetlands. CWs = constructed wetlands.

of *Ph. japonicus* in spreading by stolons, has been reported as a more prevailing species in upper-streams or small streamlets within mountainous areas of high altitudes (Byun et al., 2008; Hong et al., 2012; Park et al., 2018). In particular, it was also reported that *Ph. japonicus* usually makes a large amount of roots trapping organic matters, thereby making other plant species to easily settle in lotic wetlands (Asaeda et al., 2009).

Cattail species (Typhaceae) including *Typha angustifolia* L., *T. latifolia* L., *T. laxmannii* Lepech., and *T. orientalis* C. Presl, were one of the most common genera in the present study (Appendix 1). Among these cattail species, both *T. angustifolia* and *T. orientalis* were ranked as major vegetational components (Table 2). *Typha angustifolia* was relatively frequent in both NWs (21.5%) and CWs (32.3%), whereas *T. orientalis* was relatively common in APTs (19.7%). *Typha angustifolia* has been reported to exhibit higher growth performances than other *Typha* spp. particularly in vertical growth as well as biomass production (Hong et al., 2014; Hong and Kim, 2016). Thus, *T. angustifolia* has been frequently used as a plant material particularly in constructed wetlands for purifying water (Hong et al., 2014; Nam et al., 2018). On the other hand, in the United States, *Typha angustifolia* is considered to be a problematic species making a vigorous hybrid (*Typha* × *glauca*) with *T. latifolia* (Olson et al., 2009). In contrast, unlike other competitive *Typha* spp., *T. orientalis* was reported as a weak-competitor, explaining restricted distributions within oligotrophic wetlands such as APTs in Korea as similarly seen in our study (Park et al., 2013; Hong and Kim, 2016).

In addition to *Ph. japonicus* and *T. orientalis*, some obligate plants for wetlands (OBW) such as *Leersia japonica* (Honda) Honda, *Oenanthe javanica* (Blume) DC., and *Sium suave* Walter and a facultative plant for wetlands (FACW), *Juncus effusus* L. were ranked only in APTs (Table 2). In particular, *J. effusus* has been reported to be an essential plant species acting as a habitat for an endangered dragonfly species, *N. pygmaea* in APTs (Yoon et al., 2011). Most of all, those relatively small and short species are typical species in early phases of secondary succession in marsh-type wetlands, possibly indicating low nutrient conditions of APTs in our study (Kang et al., 2003; Park et al., 2013; Shim et al., 2013).

Wetland ecosystems of low nutrients such as APTs are also known to guarantee weak competitors such as rare species

(Kim et al., 2013; Shim et al., 2013; Hong et al., 2017, 2018b). It also appeared that heterogeneous topography (i.e., heterogeneous water levels) within APTs may attribute to diverse plant species in APTs (Hong and Kim, 2013b; Park et al., 2013; Nam et al., 2014; Hong et al., 2019b). Such varying water levels might enable diverse plant species to constitute complex assemblages in APTs (Fig. 2).

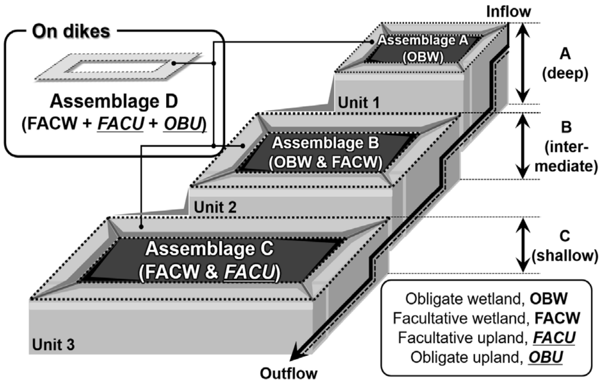

Fig. 2. A schematic diagram indicating possible assemblages in vegetation of abandoned paddy terraces (APTs) under various water levels. Units in the figure indicate individual units of APTs as a multi-cell wetland ecosystem. Four categories for plant classification were simply presented based on frequency (Choung et al., 2015) except facultative plant species (FAC).

4. Concluding remarks and implications

From our study, the potential value of APTs as a biotope type supporting diverse plant species was obviously verified via comparing APTs with other wetland types of NWs and CWs. As naturalized wetlands, APTs exhibited not only their distinctive vegetational characteristics such as small and short OBW species but also higher ecological value of plant species richness and evenness. Environmental characteristics of APTs such as low nutrients and heterogeneous topography appeared to contribute to the vegetational characteristics of APTs (Hong et al., 2012; Park et al., 2013; Nam et al., 2014).

Despite such potential value of APTs as a biotope type (Liyama et al., 2005; Park et al., 2013; Hong et al., 2019b), some studies have pointed out various types of possible threats in APTs such as invasive species (or competitive species) and environmental changes. In fact, an exotic species, *Bidens frondosa* was ranked only in APTs (Table 2). *Bidens frondosa* has been reported as an invasive wetland species in some countries such as China and Russia (Vasilveya and Papchenkov, 2011; Yan et al., 2015). In addition, *Humulus scandens* (Lour.) Merr., which was noted as a threatening species particularly in riparian wetlands (Kim and Kim, 2009), was also found as one of the major vegetational components of APTs only. This means that APTs are not only valuable biotopes for diverse plant species but also vulnerable habitats to invasive species (Hong et al., 2019b).

In addition to the biological threat, various human activities such as water level drawdown may be additional threats, deteriorating ecological value of APTs (Lee et al., 2002; Hong and Kim, 2013a; Park et al., 2013; Hong et al., 2019b). Because numerous APTs are located within montane areas of low accessibility and economic value, it can be said that most APTs are placed under potential threats from such land-use changes. Fortunately, recent studies have reported some cases of well-managed APTs by researchers, local people and government (Hong et al., 2018a; Yoo et al., 2018). Based on such cases as a benchmarking model (Katoh et al., 2009; Qiu et al., 2014), further attention on APTs as valuable biotopes supporting diverse plant species and continuous effort for management and conservation are needed more.

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