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Chapter 9

Paddy Fields as Artificial and Temporal Wetland

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Additional information is available at the end of the chapter

http://dx.doi.org/10.5772/intechopen.80581

Abstract

Paddy cultivation plays a significant and vital role on rice production. Most of the global population depends on the 480 million tons of rice produced each year as the basis for their lives. While about 90% of the world's 160 million hectares of paddy fields are in Asian countries, mainly in monsoon regions, paddies are also seen in North America and Africa, even in dry regions. Most of the paddy fields are flooded naturally or artificially during rice production period. In the case that paddy fields are kept submerged artificially, hydraulic structures are required. Irrigated paddy fields produce traditionally much rice, taking befits of stable water supply and continuous ponding. Paddy fields are simultaneously performing other functions for local environment, including climate mitigation, flood control, groundwater recharge, biodiversity, and ecosystem development. On the other hand, since paddy fields require much water and modify the original and natural hydrological regime, they might cause adverse effect on local environment. Much water supply by irrigation sometimes requires drainage system, which also might alter local water balance. In this chapter, implication of paddy fields as artificial and temporal wetland is reviewed comprehensively with various aspects, focusing mainly on their role for local hydrological environment.

Keywords: paddy field, flooding, multi-function of flooding, irrigation and drainage, hydrological environment

1. Introduction

Paddy cultivation plays a significant and vital role on rice production. Most of the global population depends on the 480 million tons of rice produced each year as the basis for their lives. While about 90% of the world's 160 million hectares of paddy fields are in Asian countries, mainly in monsoon regions, paddies are also seen in North America and Africa, even in dry regions where irrigation has reclaimed dry land for paddy fields.

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Rice, as one of the main staple for human being, is cultivated in various regions of the world from the wettest areas in the world to the driest deserts, with various conditions of natural environment including climate, topography, and soil conditions. For example, rice is grown in the area with more than 5000 mm of rain for one growing season, and with less, almost zero, of rainfall. The growing season average temperature of rice producing areas varies from more than 30°C to less than 15°C. Rice cultivation is observed in a higher mountain region with more than 2500 m above the sea level, as well as in ocean coast even in sea level region [1].

Most of the fields, where rice is produced, are flooded, or submerged by water, naturally or artificially during rice production period. To keep paddy fields submerged artificially, some infrastructures like reservoirs or ponds, intake and diversion works and canals are constructed. The infrastructures, after construction, are operated and maintained generally by local society, usually with some supports of the government. Rice is produced mostly in the fields with artificial water management with irrigation and drainage system, than in naturally flooded fields.

The stable water supply and continuous ponding in the fields are the base for much rice production. On the other hand, as mentioned above, they need hydraulic structures and the appropriate operation and management of the structures. The artificial ponding with stable and much water supply mostly results in better rice growth, while it might change the local environment both positively and negatively. In the case that the impacts of ponding and irrigation on the environment are positive, they are to be recognized as their "multi-functions." Recently, much water use for rice cultivation and necessity of water saving in paddy irrigation have been discussed often, and simultaneously the role of flooding in paddy fields has been highlighted in terms of environmental conservation (for example, see [2–4]).

On the other hand, since rice production area has been reducing in some developed countries and regions with long history of rice cultivation, like Japan, Taiwan, and Korea, the role of rice fields and their flooding is to be reevaluated. In this chapter, the irrigated fields for rice are recognized as artificial and temporal wetland and reviewed comprehensively, focusing mainly on their role for local hydrological environment.

2. Definition and outline of paddy field in the world

2.1. "Paddy field" as a farmland with rice and flooded water

The words of "paddy field" are usually and widely used for the farmland, where rice is cultivated, and they generally imply the area flooded, like the definitions of Cambridge Dictionary as "a field planted with rice growing in water" [5], Collins English Dictionary as "a flooded piece of land used for growing rice" [6], and The Free Dictionary as "a field, often flooded with water, in which rice is grown" [7]. The definition of "paddy field," however, is intricate slightly. Fundamentally "paddy" means "rice" especially in the husk. Consequently, a "paddy field" means a field planted with rice. Some dictionaries describe that only "paddy" could mean "paddy field," without any word for indicates the space, like the definition of the

Oxford Living Dictionary as "A field where rice is grown" [8], and of Merriam-Webster as "wet land in which rice is grown" [9], while it also show the meaning as "Rice before threshing or in the husk."

Since rice is usually grown in level basin flooded with water throughout most of the growing season, "paddy field" generally means "a field flooded with water for growing rice," and the definitions of "paddy field" in most of the current dictionaries include words of "rice" and "water" or "flood," as introduced above.

In Japan, the English words "paddy field" is translated to the Japanese word "*suiden*," while there this word "*suiden*" is used for flooded farm land, which distinguishes "flooded field" from "upland field" or "*hatake*" in Japanese. The upland field is not flooded and cultivated for normal crops like vegetables and flowers. Accordingly, in Japan, it is expressed that some aquatic crops like lotus and tatami are cultivated in "paddy fields." This Japanese case is recognized as an exceptional case. In this chapter, "paddy field" is to be used basically as "a field planted with rice."

As mentioned below, actually, in considerable area in the world, rice is produced in fields without flooding. Then, some parts of paddy fields of the world are not identified as the "wetland" with water submergence.

2.2. Outline of paddy field in the world

Generally, rice is a major food crop for the people in the world. Especially in the Asia region, rice is a staple food for about 2.4 billion people, and there the 90% of the world's rice is produced and consumed [10].

As summarized above, rice production and paddy fields are developed in a wide range of environments even in the arid region of the world and during the dry season. The paddy fields in dry areas sometime show very high and stable yields with much solar radiation.

The paddy fields or the environments of the rice production are classified usually based on the hydrological characteristics, since they are most essential condition to the production scheme. The most popular classification includes: (1) irrigated lowland, (2) rain-fed lowland, (3) flood prone, and (4) upland [1].

The first category "irrigated" paddy fields distributed in lowland are the area, where rice is grown in fields surrounded by ridges. Its water condition is managed by farmers, generally maintaining water depth as 5–10 cm. It covers about 90 million ha, as almost half of the world paddy area. The major portion of this irrigated area is in the Asian region.

The second category "rain-fed lowland" or "lowland rain-fed" is a field, where rice is also grown in fields with bunds, while they are flooded with rainwater for some period of a growing season. It covers about 50 million ha. There, water is flooded naturally by rain water, not fully controlled by the man-made irrigation system. These two types of paddy fields are usually predominantly puddled, and after it, rice seedlings are transplanted. These two types of paddy fields produce 75 and 19% of the world's rice production, as almost 95% of rice is

produced in the area, of which water condition is fully or partly controlled by humans like farmers.

In the third category "flood-prone field," deep-water rice and floating rice are grown in the uncontrolled flood environments, suffering periodically from excess water and deep flooding, sometime with deeper flood of 100 cm for some certain part of the growing season. This covers about 15 million ha.

The last, forth category "upland," is a field where rice is grown under dryer conditions, without ponded water, and then it is not surrounded by ridges to keep water and not equipped with irrigation system. The area of "flood-prone" and "upland" is about 11 and 15 million ha, respectively [1].

2.3. Paddy fields in the dry region

Paddy fields are found even in dry region, where rainfall effective to rice growth is not expected. They fundamentally cannot be cultivated without irrigation, where consequently rice is grown in fields with surrounding ridges to keep water. They are generally to maintain 5–10 cm of water, and usually puddled and rice are transplanted. The paddy fields reclaimed in the arid zones are recognized as the typical artificially created wetland.

Paddy fields in the dry region are irrigated and require much water to maintain flooding, since ponding water evaporates much into the atmosphere and seeps much into the soil profile that is generally much sandier compared with the paddy field in the wet regions. Basically in the dry region or dry condition, water availability is limited, and consequently the development of paddy production or paddy fields that requires much water is not preferred. Even with this constraint, actually there are many paddy fields in those conditions. There must be some reasons for the expansion of them with definite advantages.

First, the people in the dry region like the taste of rice. Second, rice contains much nutrients compared with wheat and maize as main cereal crop. Calorie per grain weight of rice is larger than wheat and maize. Protein of rice is less than them, while its quality of rice is better than others for human health. Maize contains much lipid, while its contents of rice and wheat are almost the same.

In addition to the advantage of rice in terms of the nutrients of the grain, land productivities of these crops are quite different. The weight of grains harvested per area of rice is almost 1.5 times of wheat. Furthermore, rice can be cultivated every year continuously in the same field, and the land used as paddy field can produce stable harvest.

Rice has another advantage of grain including its easiness for cooking and longer preservation. Although paddy cultivation, however, needs much labor in terms of time and efforts to maintain the field and its surrounding ridges and to perform water management, its advantages promote expansion of paddy fields even in dry region or condition.

These challenges have created the artificial wetlands in dry region.

3. Significance of water ponding in paddy fields

3.1. Water management in paddy plot

Rice cultivation has some superiority on food production mentioned above. On the other hand, paddy fields, where rice is grown, need much water due to its flooding. The main reasons why paddy fields are flooded is that most rice varieties realize better growth and produce higher yields in flooded farmland than in dry field.

In most cases, the water layer of some centimeters in a field is established usually after transplanting of rice seedlings and maintained until few weeks before harvesting. The typical water management of paddy field with standard depth of flooding for each growing stage is shown by FAO [10], and it is summarized in **Table 1** with supplemental explanation of GriSP [1].

Actual water management practices on water application and flood depth control are affected by field conditions including:

1. cultivar of rice,
2. climate and weather,
3. soil profile (water holding capacity, permeability, fertility, etc.),
4. fertilizer and chemicals (pesticide and herbicide),
5. irrigation water availability (timing and quantity),
6. drainage capacity (water conductivity of soil profile, groundwater table, etc.),
7. farm machinery,
8. labor inputs, and
9. other farming techniques.

In the improved paddy field with stable water supply and enough drainage capacity, independent water management practices of farmers are implemented, where the farmers can apply and drain water whenever they want and they introduce advanced techniques and materials.

Cultivation Stage	Growth Phase	Typical Duration	Standard Flood Depth	Remarks
		days	mm	
Field Preparation		7 - 10	none	before transplanting, 200 mm application for saturating soil profile
Early Season	Vegetative	60(55-85)	100	first roughly one-third of the vegetation stage
			20 - 50	second roughly two-thirds of the vegetation stage
Mid Season	Reproductive	30 (15-45)	100	Stages of heading and flowering
Late Season	Ripning	30(15-45)		first roughly one-fourth of the maturing stage
			none	second roughly one-fourths of the maturing stage

Table 1. Typical water management of paddy field with standard depth of flooding.

Under these conditions, the field water condition including flooding period and depth is controlled considerably. For some periods, they drain water intentionally resulting in no submergence for some periods, which is to be called intermittent irrigation or flooding [11]. If this water management is practiced, water movement in the area would be accelerated, and it affects local hydrological regime.

3.2. Advantages and disadvantages of water ponding in paddy fields

The fact that rice is cultivated under water ponding condition in most cases implies the water ponding has the advantages even if it requires much water. Main advantages of the water ponding are listed as follows:

1. stable water supply to rice,
2. suppression of weeds,
3. control of harmful insects,
4. control of temperature of rice and field (warm up and cool down),
5. supply of nutrients and control of fertilizer effects,
6. supply of necessary minerals,
7. avoidance of adverse effects of continuous cultivation,
8. leach out of accumulated salts, and
9. enhanced productivity of soil cultivation or plowing.

Most of these advantages come from stable water ponding on the field and could be potentially replaced with other materials or methods than water except stable "water" supply listed as No. 1 above.

On the other side, the water ponding induces some adverse effects on rice production and local environment. They include:

1. soil reduction due to longer submergence resulting in shortage of oxygen and emission of undesirable gases like hydrogen sulfide and methane,
2. requirement of much works to maintain ponding in the fields,
3. much water requirement for maintaining ponding resulting in water resource development,
4. difficulty on introduction of heavier machineries due to increased soil water contents,
5. growth of undesirable insects like malarial mosquito, and
6. influence on local climate due to much evapotranspiration and modified ground surface temperature.

Consequently, taking both merits and drawbacks of water ponding into account integrally in addition to field irrigation and drainage conditions, actual water management in the fields for each growing stage is performed.

4. Water management and water requirement of paddy fields

4.1. Water requirements for paddy irrigation

Water ponding in the fields requires much water. Water requirements of paddy fields compose mainly of transpiration of rice plant, evaporation from ponding water or soil surface, and percolation into soil profile. In some cases, requirement to reestablish water layer after intentional drainage and to implement flow-through irrigation for saving management labor or for control of temperature might be included.

For planning and designing the irrigation facilities and the water use plan, water requirement is basically estimated base on evapotranspiration of rice field. The actual water lost in the field through other paths, including seepage into the deeper soil profile under the root zone part and run off or spill out into the drain through the field outlet, is often recognized as the "loss," rather than "requirement."

Table 2 shows the total water requirements for one irrigation season reported by JSIDRE [12]. The total requirements range from 500 mm in Senegal to 3900 mm in Kazakhstan or 4500 mm in East Africa. This wide range is caused fundamentally by the significant difference in the seepage rates, which are estimated as none at minimum and more than 30 mm/day at maximum. The effects of water management on water requirements are to be regarded. Water requirement of paddy field in dry area is sometimes much and sometimes less than paddy field in the humid region. For example, as mentioned above, water requirement of paddy field in Egypt or Kazakhstan is relatively much, where consumption for evapotranspiration is large with drier climate, while limited water availability constrains increased water use.

Country or Region	Water Requirement mm/season	Remarks
Senegal	500 - 1,000	percolation: almost nil
Northwest China	900 - 1,500	direct sowing; 1,200 to 1,500 mm, transplanting; 900 to 1,050 mm
Brazil	1,000	equivalent to 8.6 mm/d
Texas, USA	1,200	intake: 759 mm, rainfall: 432 mm
Italy	1,600	
Australia	1,500 - 1,700	evapotranspiration: 1,200 mm
India	1,680	percolation: 1,200 mm
Cote d'Ivoire	1,920	percolation: 5 mm/d
Egypt	1,800 -2,200	
Japan	1,500 - 2,500	wide range of percolation: nil to 50 mm/d
Malaysia	2,810	evapotranspiration: 1,570 mm
Kazakhstan	3,930	
East Africa	4,500	intake: 3,600 mm, rainfall: 900 mm

(Note: Listed in order of the total amounts, source: JSIDRE in [12])

Table 2. Water requirement of paddy field per irrigation season [11].

5. Implication of paddy fields in local hydrological regime

5.1. Impacts of paddy cultivation and fields on local environment

Water ponding for rice production needs much water and also irrigation and drainage system to supply and withdraw much water to and from the fields. While the system, of course, should function well for local rice production, it could also perform for improvement of local environment. It is called as "multi-function" of paddy cultivation or paddy irrigation. The functions are fundamentally based on (1) widespread establishment of stable and shallow water body for some specific period, (2) stable water supply, and (3) adjustment of local hydrological regime.

The outcomes of the multifunction include the followings [3]:

1. reduction of flood damage in a region or basin with water storage in the fields and acceptance of flood water,
2. control of soil erosion with bunds of flat fields,
3. stable groundwater recharge with continuous percolation from water layer on the fields,
4. mitigation of local climatic variability especially drastic temperature changes based on higher specific heat of water ponded in the field,
5. establishment of conditions for fish cultivation, and
6. establishment of habitats for wildlife including aquatic flora and fauna.

These are the outcomes of paddy fields as the artificial wetlands, which are the land with surrounding ridges and the infrastructures for irrigation and drainage, as well as their management institutions and organizations in local society.

While there are many exact cases of the multifunction in the world rice cultivation areas, as the typical case with the function No. 3, the paddy fields in the Kumamoto Region, Kyushu of Japan, are to be introduced. The Kumamoto is famous as a "Groundwater City," where almost 1 million local residents depend their daily lives on the groundwater, which also enables irrigation and industry in the region. It is the fact that the groundwater is a treasured resource to support regional activities, and the stable groundwater is recharged by the percolation from the paddy fields located in the upper basin (see **Figure 1**). Now, 11 municipalities in the region share this groundwater.

In 2012, to conserve the hydrological system, the local residents, private sector representatives, and the local municipal governments established the organization "Kumamoto Groundwater Foundation." There, the function of paddy fields for stable groundwater recharge is widely recognized, and then the conservation of paddy cultivation is one of the main challenges for sustainable groundwater management. For these challenges and outcomes, the Kumamoto City received the "Water for Life Award" from the United Nations in 2013.

Paddy fields are providing wild lives with their habitats, as shown as the function No. 6 above. As one of the examples, the paddy fields in the Kohoku region of Japan, the northern shore of

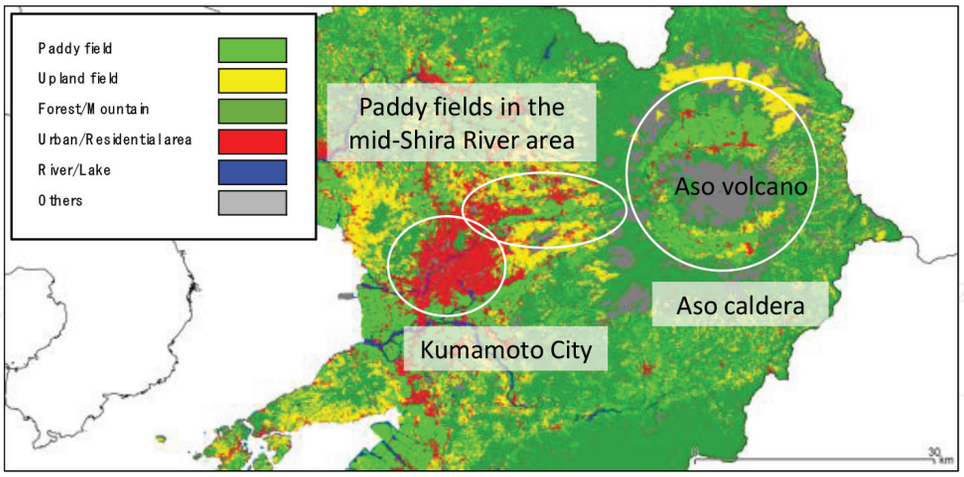


Figure 1. Paddy fields in the Kumamoto region of Japan recognized as water resource for the regional groundwater (source: Hama et al. [13]).



Photo 1. Buick swans flying onto paddy fields in the Kohoku region of Japan.

the Lake Biwa that is one of the Ramsar sites of Japan, are working as the areas for feeding the migratory birds Buick Swan. According to the detailed field observation, birds fly only to the paddy plots with water ponding, after harvesting (see **Photo 1**) [14].

5.2. Impacts of paddy fields in the dry region: the cases of Egypt and Kazakhstan

In the dry region of the world, paddy fields have been developed extensively. There, paddy cultivation and irrigation might create local "water rich condition" in regional dry environment. This impact of the artificial modification on local hydrological regime could be much larger and critical to the sustainability of cultivation and irrigation development. This is to be the typical case of the artificial and temporal wetland and suitable opportunity to reevaluate the implication of paddy fields.

Here, brief overviews of the cases of Egypt and Kazakhstan are introduced including the summary by GRiSP in the following [1].

Egypt is one of the typical countries that produce rice in dry area. It has a fast growing population with 82.5 million in 2011 leading to increased food demand. Almost all of water demand in Egypt is supplied by the Nile River, of which water is used extensively to irrigate crops including rice. Rice is one of the staple crops in Egypt and consumed 38.6 kg milled rice per person per year in 2009. Rice is grown in the summer on about 600,000 ha, mainly in the northern Nile Delta. The yield is quite high, about 9 t/ha in 2000, due to abundant solar energy and fertile alluvial soils.

The area for rice is officially regulated by the government due to limited water resources, while farmers prefer cultivating rice for its higher profit. The areas for rice producing located in the northern Nile Delta have potential risk of soil salinization. Paddy cultivation has been functioning to leach out accumulated salts in the soil profile. Salt leaching in arable soils can be supported by prevailing sub-surface drainage systems (e.g., [15, 16]).

In Kazakhstan, of which most of the land is classified as steppe or desert with annual average precipitation of 100–200 mm, wheat is a predominant crop in the northern part, whereas rice, cotton, fodder, and fruit are produced in the southern part in summer season. Its cropped area had increased due to rapid land reclamation mainly in the Syr Darya Basin since the 1950s to the 1980s, and the irrigated land became one of the big food supplying sources of the Soviet Union and Eastern Europe in that period. While rice occupies only 5–6% of the irrigated area, its water requirement is about 15% of the total irrigation requirement in that period. Most of the rice cropping area in Kazakhstan is distributed mainly in the Kzyl-Orda area of the Lower Syr Darya River Basin and some in the Ili River basin. The present total rice area is about 113,000 ha, which is equivalent to 17% of the total irrigated area. In the irrigated area in Kazakhstan, the crop rotation system is dominantly practiced with several rotation patterns, and rice is grown usually in this crop rotation system.

In Kazakhstan, large-scale irrigated agriculture has been developed since the 1960s with crop rotation including rice. In the irrigation scheme, water is applied only to paddy fields, which consists about 30% of the total scheme, and paddy fields are continuously ponded. Basically upland crop is not irrigated directly, while water required in upland fields is supplied through much percolation from paddy fields. The efficiency of conveyance and distribution is quite low due to not lined canals running through sandy soil.

Water requirement of paddy fields is around 3000 mm. Seepage from irrigation canals and deep percolation from paddy fields raise local groundwater table, and it functions as water source for upland fields surrounding the paddy fields. According to the study of the Tottori University Group, this water distribution system induces soil salinization (see [17]). In upland fields, salts accumulate during crop production with upwards water movement, while most of them are leached out when that field is cultivated with rice and flooded continuously for the rice growing season.

The large amount of water requirement for the large irrigation schemes, including much loss from the systems, needs much water diversion from the Syr Darya River, which is the main

water resource in this dry region. This large quantity of diversion is recognized as the main reason for serious desiccation of the Aral Sea.

6. Significance of paddy fields in the environment

6.1. Paddy fields in local hydrological regime

Considering the limited availability of water resources, generally, it is reasonable to recognize that paddy cultivation in dry region is not realistic or acceptable in terms of sustainability of economics and environment in many cases. Actually, most of the paddy fields are developed in the humid region with much rainfall and much available water resources. It brings that paddy fields are suitable to humid condition. This is not wrong, while it simultaneously brings another question on significance of "suitability."

The Japanese paddy fields have been reclaimed and developed historically and recently improved much with large investments for advanced irrigation and drainage system (see [18]). With advanced farming techniques including the introduction of modern cultivars, nutrients, chemicals, machineries, and so on, they are proud of higher yield and productivity of rice production as well as the qualities. It needs, however, much lasting investments and labors to maintain the systems. They are always facing risks of flood and drought damages, and the cool and hot weather damages during rice growing season. There, the paddy fields and the system are maintained by everlasting human activities as hard as possible, which have developed the infrastructures, institutions, and interconnectedness in the society. This situation has been developed under the condition of climate and small-scale topography and river system, which are relatively controllable comparing with the continental conditions. Thinking over these history and present system, we can ask "Are the paddy fields in Japan suitable to its natural condition?" Some paddy fields in other regions can produce considerable yield without any hard investment, while its yield is not so high. This could be recognized as "naturally" suitable.

The point to be recognized here is just that the "suitability" of the paddy fields to the natural, and climate condition is not to be evaluated absolutely. It needs comprehensive conclusion, especially assessment in terms of sound hydrological cycle of the region or basin. Paddy cultivation and fields are to be arranged appropriately in the hydrological regime of the region. Then, consequently, we might find "suitable" and "sustainable" development of paddy fields in each region including dry area, which are to be located in right place in the local hydrological system.

6.2. Impacts of reduced paddy fields on local environment

In the past few decades, in some developed countries and regions with long history of rice production, like Japan, Taiwan, and Korea, the area of paddy fields has been reducing, due to the changes of dieting system according to economic development and globalization, as shown in **Figures 2** and **3**. This reduction of paddy area might result in losing their multifunction with reduced rice production.

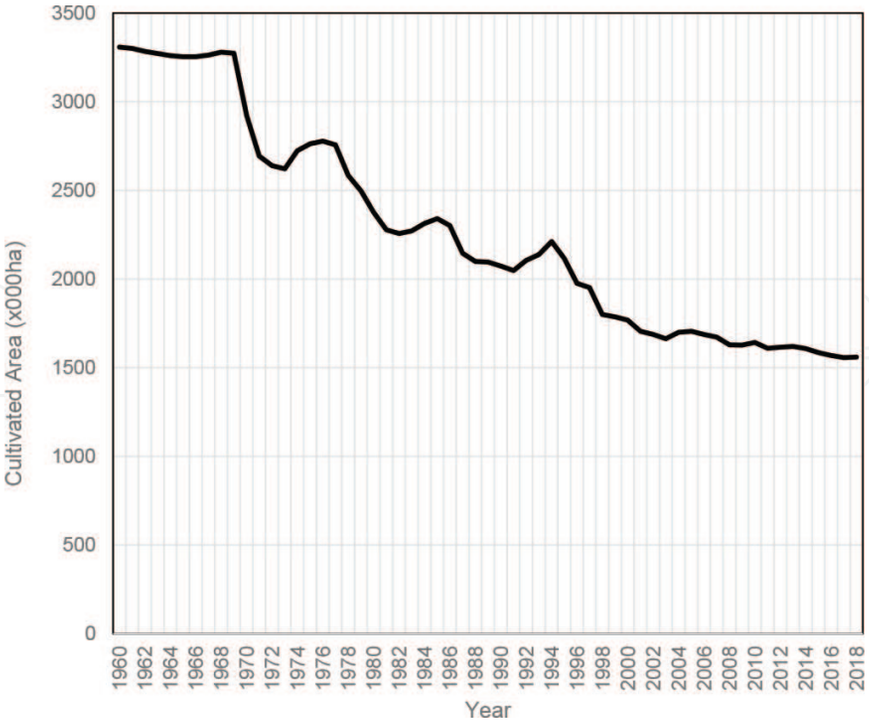


Figure 2. Changes of paddy cultivation area in Japan (source: [9, 19]).

The Japanese case of the reduction of paddy field area and its consequences are quickly reviewed. Japan had tried to establish complete self-sufficiency of rice historically, especially after the World War II. And then, it is finally realized in the 1960s, after long development investigation for improvement of paddy cultivation and fields including farming techniques and infrastructures of it.

Just after the reach to complete self-sufficiency, it had faced to the problem of over production of rice, which was caused by higher yield of rice, reduction of rice consumption with increased consumption of other food, including bread, meat as well as vegetables. The government asked farmers to convert their farm fields from rice to other crops with some portion of their farming plots, providing some subsidies. The rapid industrialization and urbanization also require paddy fields in the plain to be transferred to urban use. Consequently, the area of rice cultivation area has been decreasing as from about 3.3 million ha in 1960 to 1.56 million ha in 2017. It is a drastic reduction (**Figure 2**). During the same period, the rice consumption per capita per year of Japan has drastically reduced from about 127 to about 68 kg (**Figure 3**) [19].

With these changes, it could be easily recognized that the water ponding area, that is temporal water body or wetland, has reduced to the half of the peak, and the hydrological environment has been affected. It also means the degradation of multifunction of paddy fields. The wildlife is losing their habitats, and the biodiversity and the ecosystem developed historically have been modified.

In Japan, another problem is a reduction of farmers and their successors, which is another constraint to conserve paddy areas. The reduction of paddy fields means not only reduction of

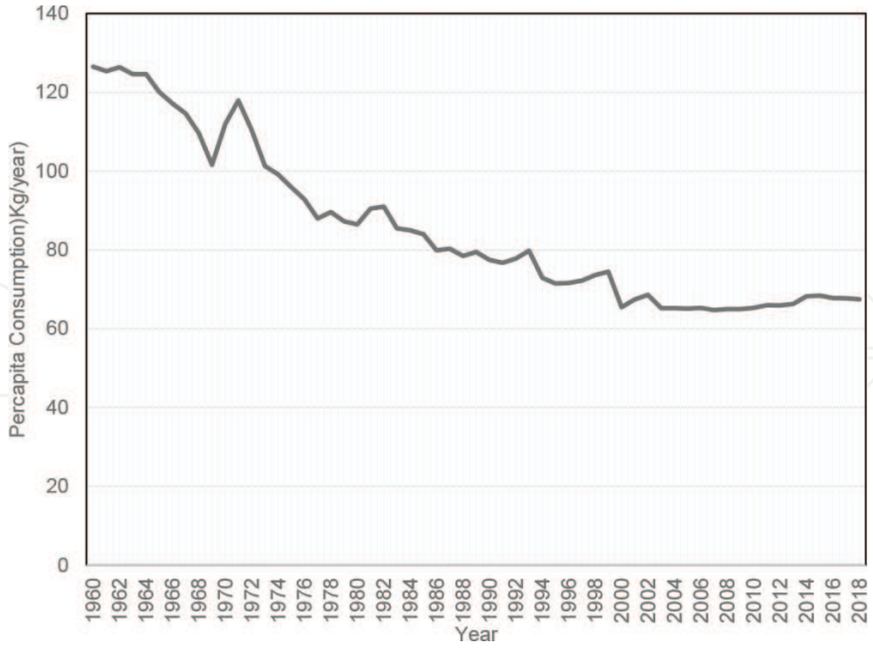


Figure 3. Changes of rice consumption in Japan (source: [9, 19]).

rice production but also induces the changes of paddy irrigation system in the basin. The significance of paddy fields is to be reevaluated and reappreciated in terms of conserving the natural environment and sustaining the rural society and culture. The Japanese governments are challenging to revitalize agriculture and communities in rural areas, with some policy for conserving ecology and environment in rural area. The similar situation of reduced rice consumption and paddy fields are seen in Korea and Taiwan.

7. Summary: concluding remarks

In this chapter, implication of paddy cultivation and paddy fields is reviewed, focusing on flooding in the fields including its reasons and consequences.

It is clear that paddy fields, paddy cultivation, and paddy irrigation need much water, land reclamation and preparation, and system to distribute water. Therefore, they have developed infrastructure, institution as well as interconnectedness of the farmers and other stakeholders.

Significance of paddy fields as the artificial, temporal/seasonal wetland is to be assessed in comprehensive manner with aspects of agriculture, eco-environment, and hydrology. Since they use much water and might alter the local water balance and ecoenvironmental system with adverse effects, they are to be arranged appropriately in the hydrological and environmental regime of the region. Local communities established with paddy fields are to be organized continuously as the base for the society and culture and the potential to manage the future changes of environments.

In addition, it is urgent to reevaluate the role and implication of paddy cultivation and fields in the local system under the changing climate.

Acknowledgements

Discussion in chapter about implication of paddy cultivation and field has been elaborated with communication in the society on paddy field including the International Society of Paddy and Water Environment Engineering (PAWEES). This study is partially supported by the Sosei and Togo Programs of the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT), and the KAKENHI Grant Number JP16H02763 of Japan Society for Promotion of Science (JSPS).

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