Paddy Fields in the World

Edited by

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JSIDRE

The Japanese Society of
Irrigation, Drainage and
Reclamation Engineering

Paddy Fields
in the World

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Preface

We are confronted with the difficult problems of world food production and the global environment as the next century approaches. Increases in crop yields and expansion of agricultural land both have contributed to food production during the second half of the 20th century. However, remarkable increases in yield by applying advanced technologies to feed the rapid growth of world population are not expected in the future. Development of new agricultural lands will be restricted in order to conserve nature and the environment of each country. On the other hand, vast areas of agricultural land have been lost every year to desertification, salinization, soil erosion and urbanization. Under such conditions we must prevent soil degradation and keep the productive and fertile land for food production.

More than several thousand years ago, rice cultivation began in some areas in Asia, and rice has fed the dense human population. Paddy fields have been used for continuous rice mono-cropping without reducing yield, and higher yields have been produced than those of other upland crops. Sustainable and stable production of rice in paddy fields must be studied throughout the world to further increase production for the next generation. There are various types of paddy fields in the world influenced by climatic, geographical, cultural and socioeconomic conditions. It is necessary to create appropriate fields for rice production under specific natural and cultural conditions based upon a field survey and a comparative study of paddy fields around the world.

Professor Emeritus Fujio YAMAZAKI, University of Tokyo, donated funds to the JSIDRE for studying the irrigation, drainage and infrastructure of paddy fields in foreign countries. In response, JSIDRE organized a committee and established a research project on **Paddy Field Engineering** in 1989. The committee recommended a survey of paddy fields under different natural and social conditions. Typical paddy fields in the U.S.A., China, West Africa, Thailand, Egypt and Bangladesh were chosen as the subjects for study. Field surveying focused on soil and water management, shape and area of a field plot, allocation of irrigation and drainage facilities and roads, cultivation technology and environmental issues. In addition, paddy fields in Australia, Brazil, Northeast part of China, India, Indonesia, Italy, Kazakhstan, Korea, Malaysia, Philippines and East Africa were also described by authors who have ever been concerned in paddy fields in these countries and regions.

This book consists of two parts. The results of the survey of individual paddy fields in 20 countries and regions are reported in part I. One general and five specific topics relevant to paddy field engineering are described in part II based on the comparative study. However, this book is mainly written by Japanese reseachers based upon the limited numbers of field surveys, and some room for study remains. We welcome the comments of readers and anticipate carrying out further field surveys on both rice production and environmental conservation.

Two international workshops, *Physical Aspects of Soil Management in Rice-based Cropping Systems* (held at The International Rice Research Institute in 1984) and *Soil and Water Engineering for Paddy Field Management* (held at the Asian Institute of Technology in 1992), gave us a chance to re-recognize the functions of paddy fields in rice production and encouraged us to study paddy fields in the world in detail. We should establish a style of paddy field engineering that is acceptable to farmers producing rice without disturbing wetland ecosystems.

Finally, we express our sincere thanks to farmers, scientists and engineers of the individual countries for their help and suggestions on our survey, and to the authors who permitted us to reproduce figures and tables in this text.

This book is dedicated to the late Dr. Fujio YAMAZAKI who loved paddy fields and devoted his life to their study. The Paddy Field Engineering project was made possible by the fund he established.

September 1995

Toshio TABUCHI
Shuichi HASEGAWA

Fujio YAMAZAKI
Rice terraces with snow

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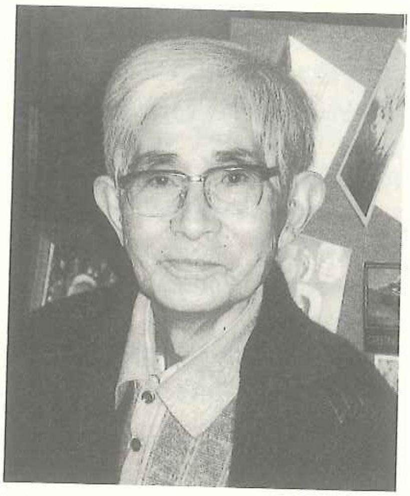

This book is dedicated to
the late Prof. Fujio Yamazaki

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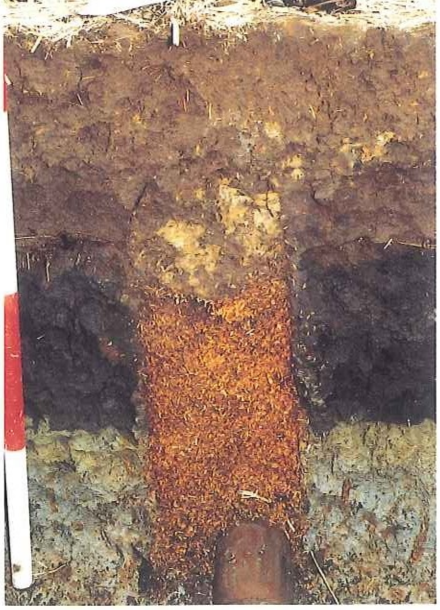
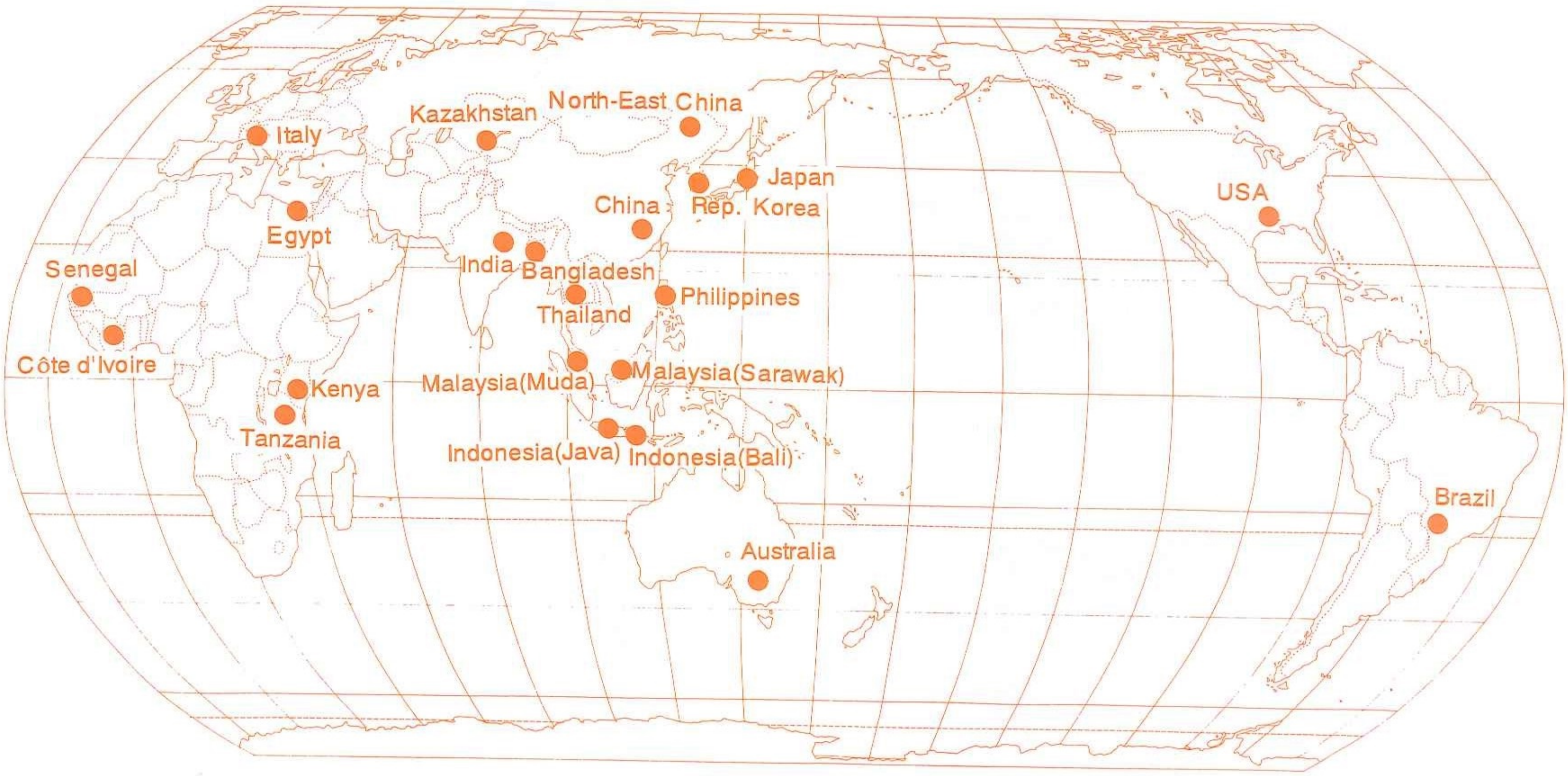


Underdrain in paddy field
(rice husks as surround material
of a drain pipe)

Re-shaping of large-sized paddy fields in Australia

Rice terraces in Ifugao, Philippines



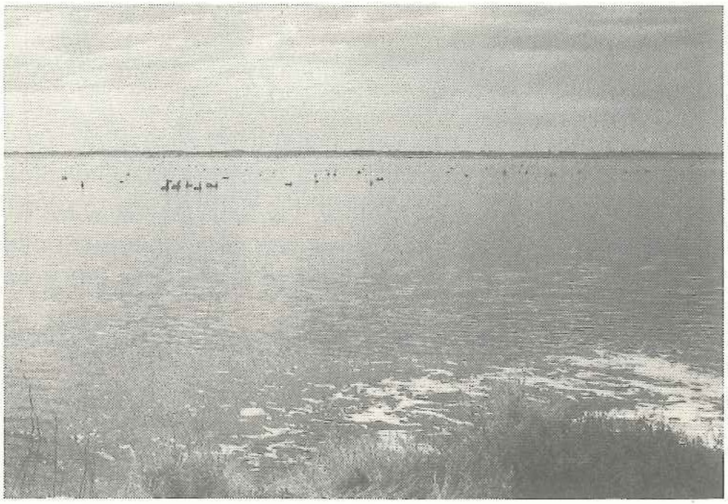
Locations of countries reported in part I

Part I

Various Types of Paddy Fields in the World

I-1
Paddy Fields and Evaporation Basin in Australia

Toshio TABUCHI* and Eiji YAMAJI*



Australia's rice growing is superior to other countries in both land productivity and labor productivity. To maintain this position, large-sized paddy field has been re-shaped to have straight bunds. But serious problem accompanying rice cultivation is existing, i.e. the shallow and saline groundwater problem. So, soil compaction and puddling to reduce percolation is in research. And, collecting wells and network conveying to giant evaporation basins (**photo.**) are the special method to remove saline groundwater, giving typical characteristic to Australian paddy growing.

I. Introduction

Australia produces both industrial and agricultural products, exporting wheat, wool and sugar at the first grade in the world. It has vast agricultural areas; 4.7 billion ha of arable and orchard and 44 billion ha of pastures and meadows. These areas share 6% and 57% of whole national land respectively. But agricultural workers share only 5% of all industries.

Climate of Australia is diversified corresponding to vast national land. Northern part belongs to tropical climate zone, eastern coastal area and south-western coastal area belong to temperate climate zone. The rest, 70% of national land is in arid and semiarid zone.

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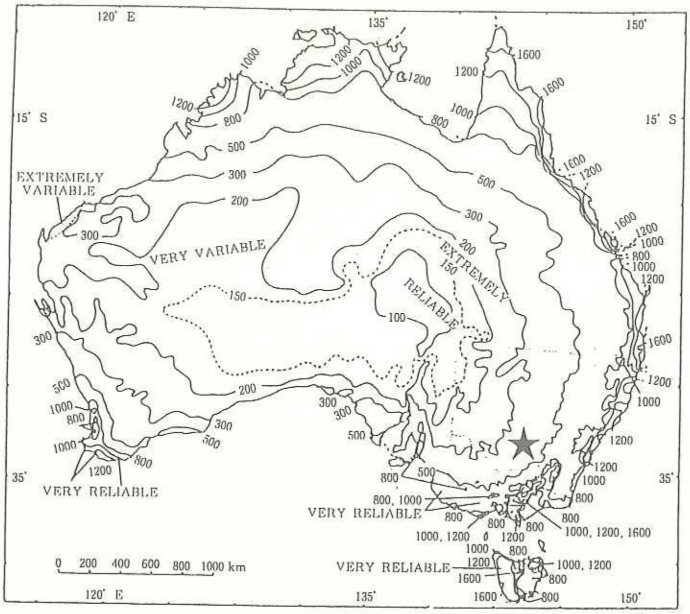

Figure 1 Distribution of precipitation and rice growing area (★) (Jeans, 1986)

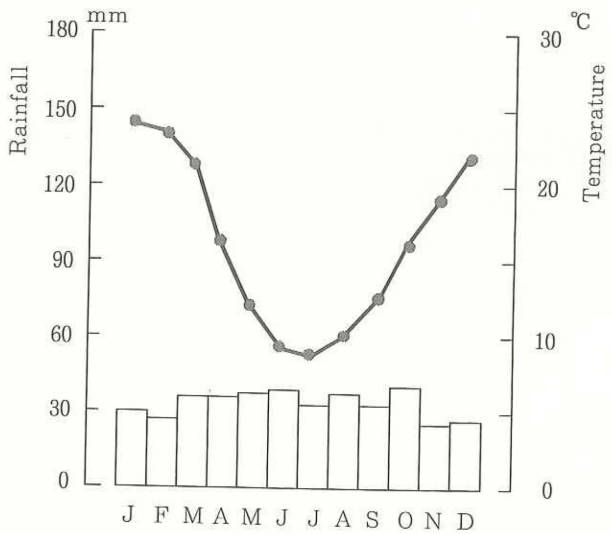

Figure 2 Monthly precipitation and temperature at Griffith City

Figure 1 shows the distribution of annual precipitation. The area receiving more than 1,000mm of rain is limited within small zone. The symbol ★ shows the rice growing area in New South Wales (NSW) state. This area produces 95% of the national rice production. There are also some rice growing area in north-eastern coast of the Continent.

Figure 2 shows the climatic conditions in rice growing area. Temperature

Table 1 Change of area, yield and production (Cribb, 1987)

Production Year	80/81	81/82	82/83	83/84	84/85
Area (1,000 ha)	104	123	85	119	127
Production (1,000 t)					
long grain	258	213	181	178	204
medium grain	470	641	367	454	660
total	728	854	548	632	864
Yield (t/ha)	7.0	6.9	6.4	5.3	6.8
Export, milled (t)	276	558	384	241	327

and sunlight in summer are high enough and diurnal range of the temperature is wide in this area, so the efficiency of photosynthesis is very high. But irrigation is necessary for any crop growth due to shortage of rainfall.

In Australia, long and medium grain rice are grown. Annual production is roughly 800,000 t and about half of it is exported. The remainder is disposed into the Australian market as table rice, broken rice for food processing, rice flour for food processing and a variety of by-products.

II. Field System and Water Management

1. Field structure

Structure of paddy field was constructed under influence of paddy field of California, USA. The area surrounded by roads and canals is the basic unit of rice cultivation called as "Paddock" (**Figure 3**). One paddock is divided into some pieces called "Bay". Size of paddock is 300~700m × 300~700 m, so the area is about 20~50 ha. Size and shape of bay are decided by topographic conditions and the method of water management.

2. Irrigation system

Three big irrigation areas are distributed in the basins of Murrumbidgee river and Murray river as shown in **Figure 4**. Water is stored in big dams; Burrinjuck dam 1,000 × 10^6 m^3, Blowering dam 1,600 × 10^6 m^3 and Hume dam 3,000 × 10^6 m^3.

In MIA, Murrunbidgee Irrigation Area, irrigation water is taken at the Berembed Weir and supplied to 2,570 farms by the canal. Irrigated area is 190,000 ha in which rice is planted in about 40,000 ha (21%). Total amount of

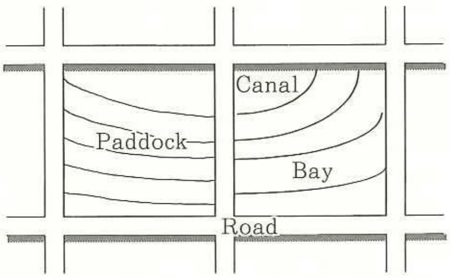

Figure 3 Conventional field structure

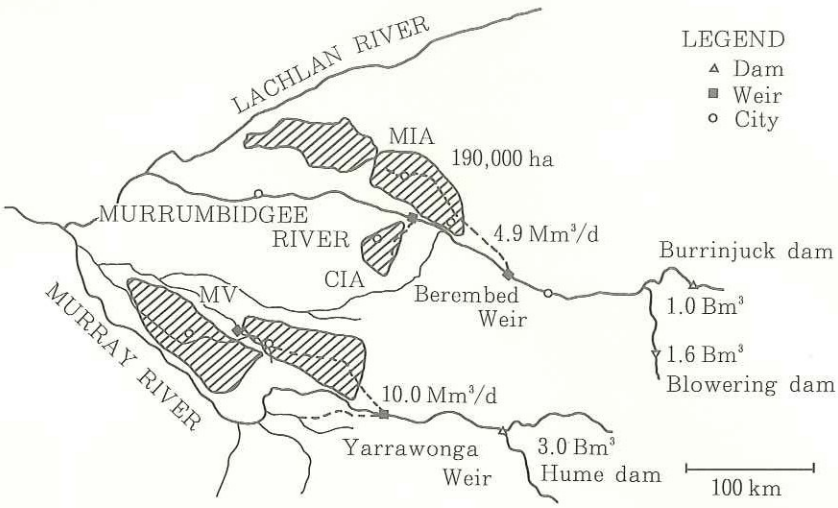

Figure 4 Irrigation system of rice planted area

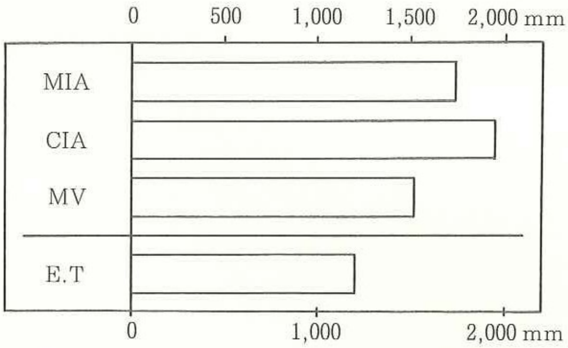

Figure 5 Water requirement in each irrigation area and evapotranspiration (Source: Glampett, 1984)

irrigated water is about 700×10^6 m³ and about 50% of water is used for rice, 25% is for other crops and 25% is estimated as seepage loss from the canals.

In MV, Murray Valley Irrigation District, rice fields is about 56,000 ha and CIA, Coleambally Irrigation Area, is 24,000 ha. In these areas, ratio of paddy field to total crop area is around 25% and 15%, respectively.

3. Water requirement

Water requirements in each district are shown in **Figure 5**. The values of MIA and MV are 1,500 mm~1,700 mm. Evapotranspiration is 1,200 mm, which corresponds to 80% of total water. The loss due to deep percolation and surface drainage is less than 500 mm.

Recently it is considered that rice growing should be restricted to paddocks where rice-water use was less than 1,600 mm in order to prevent waterlogging problems. This means that sum of surface drainage and deep percolation should not exceed 400 mm.

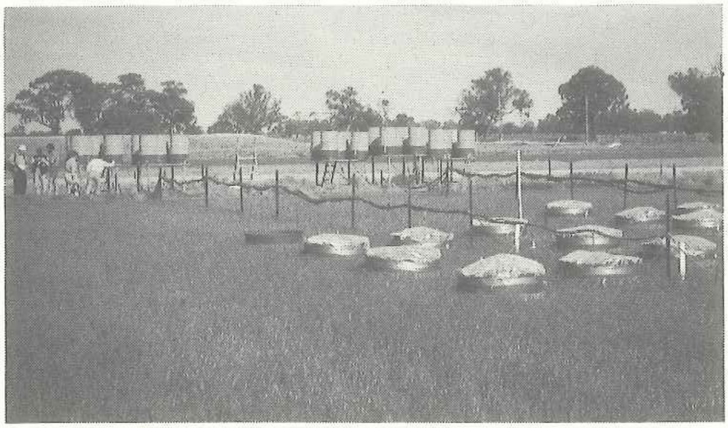

Photo. 1 Test field for percolation control

Assuming 5% available porosity in the soil profile and no downward leakage or lateral flow, an addition of 100 mm is equivalent to a rise in the water table of 2 m. Actual rates of water table rise have been in the range of 0.5 to 2 m/y.

4. Percolation control

Percolation rate is usually not so high due to impervious clayey soil. However, percolation causes rise of groundwater table and it causes serious saline damages to other crops. Accordingly, experiments on percolation control by compaction and puddling are carried out (Humphreys, E. et al., 1992). Big rings (1.2 m) with a big Mariotte siphon are used to measure percolation rate as shown in **Photo. 1**. Average percolation rate of puddled plot was 3 mm/d and 4 mm/d in the compacted plot.

III. Rise of Groundwater Table and Giant Evaporation Pond

In 1983, the area of shallow groundwater table attained 200,000 ha due to irrigation. Orchards and upland crops had great damages caused by wettness and salinization . This problem is common in all the three irrigation areas. It is predicted that 30% of the agricultural land in the MIA area could become salt-affected in the longer term, with 15% seriously salt-affected. In the CIA, over 50% of the landscape had a water table within 2 m of the soil surface in 1991. Water tables are also rising in the MV area. In the Wakool-Tullakool district, 57,000 ha were at the risk of salinization by 1975.

In order to stop rising groundwater table, groundwater can be pumped up, but this water is not allowed to be drained into canals and rivers due to high salt concentration.

Accordingly, the giant evaporation ponds were designed and constructed (see front page). The area of the first pond is 770 ha and the second one is 1,300 ha, total 2,100 ha, as shown in **Figure 6**. Construction cost is 28 million A$*. The

Part II

Paddy Field Engineering

II-1
Basic Aspects of Paddy Fields

Jutaro KARUBE*, Shuichi HASEGAWA**, Yukio TOYOMITSU***,
Kazuhide ADACHI**** and Atsushi TADA*****

I. What Is a Paddy Field ?

1. "Ponding" for rice cultivation distinguishes paddy fields from upland fields

Eighty-seven percent of the land used for rice cultivation in the world is ponded, although rice has varieties ranging from floating to upland. Upland rice, which is grown in an upland dry field, is cultivated basically the same way as other upland crops. As it produces a less stable yield, upland rice is grown only on fields that cannot be ponded.

Rice is grown mostly under ponding conditions not only for the purpose of supplemental irrigation. Ponding creates the best environment for rice cultivation, making the best use of the property of rice as an aquatic plant which can transmit oxygen from the leaf to the root through the stem.

As the rice plant has natural properties adaptable to both ponding and dry conditions, it can grow in fields difficult to distinguish clearly as paddy field or another type. In addition, there are paddy fields under rotational cropping with upland crops. Consequently, the definition of a paddy field may be vague. The properties of paddy fields listed below are important as criteria.

The advantages of ponding in paddy fields are as follows.

a) Minerals and nutrients dissolved in water are supplied to rice plants and soil by irrigation. Because of the large quantity of irrigation water, this effect is not small. Fertile clays are also supplied by floods.

b) Ponding water moderates the thermal conditions and prevent the crop from being damaged by cold and hot temperatures.

c) Ponding water controls weeds, especially dry field weeds or C4 plants.

d) As soil becomes reductive by ponding, the decomposition rate of organic manure is slow in temperate climate areas. Using this characteristic, farmers can control soil nutrients by water management.

e) Following the pH increase with soil reduction, phosphate and iron become soluble and usable by rice plants.

f) Under reductive conditions, nitrogen exists as positive ammonium ions and is held on clay surfaces with negative charges to be used effectively by rice plants.

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This behavior of ammonium is quite environment-preservative, different from that in upland fields, where groundwater contamination with nitrate is becoming a serious problem.

g) It is impossible for pathogenic bacteria and nematode to live in paddy soil in a reductive condition. Therefore, no growth injury to rice plants in paddy field is caused by continuous cropping.

h) As paddy soil is saturated with water, nutrients easily migrate toward the plant root to be absorbed, so rice plants grow well even under a low nutrient concentration.

i) Aquatic nitrogen fixing organisms grow and work as nitrogen suppliers under ponding condition, especially in tropical areas.

j) From the viewpoint of environmental protection, the paddy field serves the function of water quality improvement by dinitrification of nitrate that comes out of the surrounding upland field.

k) A paddy field serves the functions of soil conservation, flood control, and groundwater recharge due to the water reservable structure. In Japan, total reservable volume of water in paddy fields is estimated to be double of the flood volume controllable by dams. Thus, the paddy field plays a major in role for preventing natural hazards and securing water resources.

Based on the many excellent properties listed above, the paddy field is a highly productive, sustainable, and environmentally protective rice field. Rice is easy to cook, and is a healthful food as it is nutritionally well balanced and low insulin-inductive.

However, there will be restrictions on developing and using a paddy field.

a) There must be abundant water resources for developing a paddy field, because ponding irrigation needs more water than ordinary field irrigation. However, a water reuse system is quite effective for minimizing actual water consumption.

b) No little expense or labor is required to consolidate a flat horizontal field with bunds for ponding, canal systems for irrigation and drainage, farm roads, etc.

c) A special working system is necessary for mechanization as the soil bearing capacity is decreased by ponding.

d) There are no other crops besides rice suitable for ponding cultivation on paddy fields.

2. The structure of a paddy field

Paddy field usually needs a proper structure for ponding irrigation and drainage, even though ponding takes place naturally by rain in areas with proper configuration. So, in general, paddy field will be consolidated with the structure developed as follows.

a) Guarantee the water sources, and construct an irrigation system.

b) Level the soil surface as precisely as possible to make the ponding depth uniform.

c) Surround the field with bunds to keep water about 10 cm in depth.

d) If it is an overpercolating field, an artificial low permeable layer should be made.

e) A drainage canal system is necessary for proper water management and for harvesting by machinery.

f) Bunds, irrigation canals, drainage canals, and farm roads should be properly arranged.

3. Rotational cropping, or crop diversification in paddy fields

A paddy field is a special field in which rice can grow continuously. Upland crops also can grow on the same field, unless it is badly drained. If paddy rice is combined rotationally with upland crops, it can effectively refresh the soil against growth injury for upland crops. It saves irrigation water, and can be effective for rice production control. Consequently, rotational cropping with rice and upland crops in paddy field, a process which is also called crop diversification, is spreading in the self-sufficient countries. The following are the characteristic features of single cropping and rotational cropping in paddy fields.

1) Single cropping of rice

Single cropping produces the highest yield per crop since the best season can be chosen for cultivation. Typical cases of single cropping are as follows:

a) In a temperate zone where double cropping is climatically difficult.

b) In an ill-drained area where rice double cropping is climatically difficult.

c) In a temperate zone where rice double cropping is climatically difficult, and no other suitable crops can be grown for economic reasons.

d) In a tropical or subtropical monsoon area where it is difficult to crop twice due to water shortage during the dry season.

2) Double to triple cropping of rice

Rice can be grown continuously twice a year in irrigable paddy fields in tropical or subtropical areas and some parts of temperate zones. In a tropical area, since rice can be grown any time as long as water is available, cropping five times in two years or triple cropping in one year is possible. Even in that case, having a fallow term for about one month in the dry season is effective against diseases and insects, for recovery of soil bearing capacity, and for saving water (Kitamura, 1987). Yield per crop is lower than with single cropping.

3) Double cropping and rotational cropping

Annual rotational cropping of rice and wheat or a forage crop is prevalent in the temperate zone in China. The same cropping style was popular in Japan until a few decades ago. This is a typical intensive land use of paddy fields in a temperate zone.

Rotational cropping is one of the most intensive ways to use land if there are suitable upland crops. Farmers are often advised to rotate rice (2~3 crops), vegetables and beans in a period from 1.5 to 3 years.

Some problems may arise with rotational cropping in a paddy field. Unfavorable soil tilth and low percolation often result when upland crops follow paddy rice. On the other hand, when rice takes over the upland crops, greater amounts of irrigation water may be necessary since the soil may develop more highly percolative properties.