ISSN 0919-8822
March 2012
No.63

JIRCAS Newsletter for INTERNATIONAL COLLABORATION

In This Issue

JIRCAS
JAPAN INTERNATIONAL RESEARCH CENTER FOR AGRICULTURAL SCIENCES

The Water Century'

In this issue, we are featuring the theme of 'Water'. It is common knowledge that water is essential for human life and food production. However, the emerging global crisis in water supply is relatively unknown.

Earth is called the 'water planet'. However, 97.5% of the Earth's water is seawater and the amount of freshwater available for human consumption accounts for only the remaining 2.5%. Moreover, most of the freshwater exists in the South Pole region, or in the form of glaciers and groundwater, and the more accessible freshwater of lakes and rivers accounts for no more than 0.3%.

Important issues concerning this precious water resource include management for conservation of its total volume, lack of alternative resources and wide variations in its availability, both in location and time period. A glimmer of hope lies in the fact that the Earth's total water volume has not significantly decreased because water circulates on the planet. However, the zero net increase of water implies that there are intrinsic limits to beneficial food production activities, and by extension, the existence of mankind. We can only wonder how long the water on Earth can support its explosive and historically unparalleled population growth and the resulting dramatic increases in food demand.

One expected impact of global warming—which is already being felt—is the increasing frequency of extraordinarily devastating floods and droughts worldwide. This will have a significant impact on the conventional concept of uneven distribution of water resources, and may drastically alter the shape and characteristics of food production areas and production volumes. It is estimated that water consumption for food production accounts for approximately 70% of the freshwater used on Earth. This suggests that global changes in water availability will have a significant impact on food production, while simultaneously offering opportunities for food production technologies to provide breakthroughs in resolving the water crisis. We thus need to exercise wisdom in addressing such vast and complex issues by developing, for example, irrigation and cultivation technologies aimed at water conservation and flood protection for farmlands and crops.

Since 1960, when it stood at three billion, the world's population has doubled over the past 50 years, and has already reached seven billion as of October 31, 2011. However, the total volume of freshwater circulating on the Earth has remained unchanged. In addition, climate changes and the resulting floods and droughts have intensified, which have made the preservation and utilization of precious water resources increasingly difficult.

The current situation is well described by the phrase, 'The Water Century', which envisions the 21st century as an era of political and even military struggle over water resources, similar to the struggles over oil resources in the 20th century. Indeed, the environmental and social circumstances surrounding water resources would appear to warrant little optimism. Thus, it is of great importance to conserve water resources, which are one of the 'global public resources' for food production, and by extension, the survival of mankind. From this perspective, now is the time to develop effective water management technologies and an international administrative system for the efficient use of water, especially in regions with wide variations in freshwater availability. Concomitantly, the Japan International Research Center for Agricultural Sciences (JIRCAS) seeks to contribute to the resolution of the water crisis and to enhance scientific knowledge through research in developing countries.

Masami Yasunaka
Vice President, JIRCAS

Water for Agriculture in the World

Massive water requirement for agriculture

In any of the various and diverse agricultures in the world whether in developing countries to developed ones, from humid to arid regions, water, along with land, is an essential resource for agricultural production. Extensively invested and low-cost water and land resources are used on a massive scale for agriculture in general, while intensively invested and high-cost water and land resources are used for economic activities in cities.

Consequently, annual water use for agriculture amounts to 2,745 billion m^3 and accounts for some 70% of the world's total fresh water use for all human activities that runs up to 3,909 billion m^3. The remaining 30% of it is used for domestic, industrial, hydro-electric and other purposes (Fig.1).

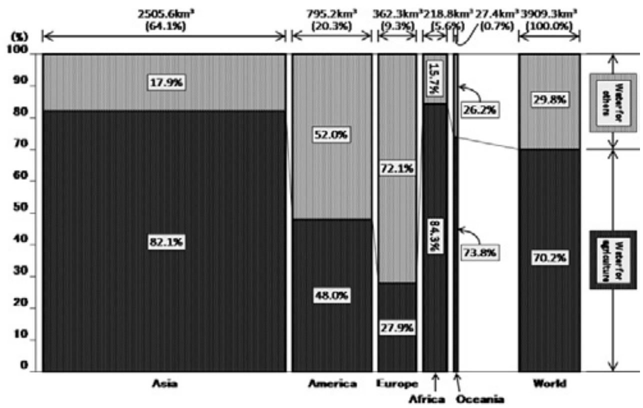

Fig. 1. Annual water withdrawal and proportion of agricultural water use by continent
(Data : AQUASTAT main country database.
(http://www.fao.org/nr/water/aquastat/dbase/index.stm)

Agricultural use of water resources differs from urban and industrial uses because of the fact that the former can utilize direct rainfall on the exact spot of water use, viz. cultivated lands. It also means, in the other sense, that food and other agricultural production activities are apt to be deeply affected by changeable weather conditions.

Rice farming in water-rich humid regions

Farmers can effectively cultivate various farm products using only direct rainfall on croplands in warm and humid regions where it rains abundantly. This is called rainfed agriculture. However, poorly drained croplands in such regions usually result in oftentimes inundated plants that lead to waterlogged and rotting roots in oxygen-starved soils. Rice, as a water-loving plant, has a physiology which allows it to survive these conditions. It is well adapted to extremely wet conditions because it can draw oxygen into its roots and through the trunk due to its distinct anatomical structure which is equipped with good air passages. Farmers can kill two birds with one stone by rice farming because, besides the above-mentioned advantage, weeds can't grow thickly in immersed cultivation whereby the entire field is continuously submerged under water.

However, unexpected drought usually creates serious damages in crop harvests of rainfed farming. But water from a welcome rain is a blessing during drought. Therefore, if farmers want to secure crop production, they need ideas on how to preserve water resources during such period when they expect a certain amount of rainfall, to be stored as a kind of insurance for any unexpected drought. Standing pools of water in paddy fields surrounded by levees is one of those strategies. While artificial farm ponds are systems larger than standing pools of water, and dam reservoirs are larger than ponds. Underground water is also useful as a relief in emergency but it entails high cost for pumping up.

Irrigated agriculture with higher productivity than rainfed one

We refer to irrigated agriculture as farming which uses water originating from dam reservoirs, farm ponds, natural lakes and marshes, drawn from rivers and introduced to farmlands through canals. Irrigation is important as a kind of insurance during drought. In addition, it actively allows better control of soil moisture and results in a great increase in yield of crops. It is common knowledge, for example, that the adoption of chemical fertilizers shows remarkably better performance because plants can more actively assimilate soil nutrients under a moisture-rich condition of the farm soil. High yield varieties exhibit better performance under such environments. But on the other hand, they easily rot and result in no harvest under the condition of insufficient moisture in the farm soil while indigenous low yield varieties can still survive and bring in a harvest.

Therefore, farmers can obtain great harvest in irrigated agriculture with minimum risks when they introduce high-yielding varieties and they can input chemical fertilizers more effectively as compared with rainfed agriculture where an unstable condition of soil moisture exists. Irrigated farmlands account for only 17% of arable lands worldwide equivalent to 1.5 billion ha but some 40% of world crop production is earmarked from them to support the global demand for food.

We can also see unique irrigation systems in humid regions, such as the "colmatage" canals along the Mekong River in Cambodia. This allows artificial flooding by allowing river water to flow into the farms through opened river dikes and sluices during the rainy season and then the farmers trap water by building levees when the flood water retreats at the beginning of the dry season. This is called flood-recession rice farming. Farmers around Tonle Sap Lake, also in Cambodia, trap the retreating water in vast areas to manage recession rice farming by utilizing the natural rise and fall of the water level of the lake.

Indispensable irrigation in arid regions

Meanwhile, though not situated in humid regions with ample precipitation, farmers can cultivate rainfed crops such as wheat, potatoes and peas which are tolerant to rather dry weather in semi-arid regions where annual precipitation amounts in the range of 500-700 mm. On the other hand, in arid regions where annual precipitation is less than 500 mm, raising rainfed crops is difficult so that pasturing livestock becomes a common livelihood. It is necessary for farmers to irrigate using underground water, reserved rainfalls or temporary flooding before the cropping season when they want to grow plants there. Once water becomes available, arid regions can turn into great granaries because of their advantage in being blessed with fine weather and sufficient sunshine.

For example, farmers in arid regions such as in the Middle East, Central Asia and North Africa have practiced from long time ago an irrigated agriculture using a groundwater system called Quanat. This is an irrigation system which was acquired and passed down since B.C. in the hilly areas of desert zones. It has vertical wells dug at regular intervals around and halfway down a hill to the skirts of which the bottoms are connected by a horizontal canal with a total length of hundreds to tens of thousands of meters. Groundwater is collected at the bottom of the most upstream vertical well and the water flows into the horizontal canal. If we design it setting the altitude of its most downstream well to the same level as the ground surface, it will become an open channel and we can easily obtain water from it.

Another farming system known as water harvesting is also familiar in arid regions. In this system, farmers set aside the elevated parts of their farmlands as catchment areas for rainwater and cultivate crops in the lower parts and hollows of their lands where rainwater flows into and concentrates hence stored. This is an intermediate system between rainfed farming and small-scale irrigation which is self-contained within the bounds of their own farmlands.

Dilemma of farming in arid regions

Modern technological innovation has allowed two types of large-scale irrigation farming in arid regions. The first is a system with long channels and rivers conveying water stored in big reservoirs constructed in remote areas which receive heavy rainfall. We can find it in Israel, in the middle to southern parts of California in the United States and the southeast parts of inland Australia. For instance, the California Aqueduct is a 710 km-long canal conveying water from northern to southern California and it irrigates 3.11 million ha wide farmlands for the largest agricultural production area in the United States.

The second is a system with deep wells by which groundwater is pumped up from aquifers. It may be accompanied by large-scale center pivot machinery which allows irrigation for uneven or hilly terrain where traditional methods of irrigation may not be an option. We can find it in the Middle West, Saudi Arabia, in the United States, India, Pakistan, North China Plains and Northern Africa. However, the over-pumping of groundwater which exceeds the natural replenishment rate of the aquifer causes serious falling levels of groundwater and depletion of water resources in just a matter of several decades,for water which had been slowly stored and replenished by nature for tens of thousands of years before.

The problem common to the two types of irrigation in arid regions is soil salinization. Saline water moving up from the rock-salt layer deep in the underground to the surface of the earth is caused by a capillary phenomenon which occurs when excessive irrigation water infiltrates into the layer. From large-scale irrigation areas in the ancient era of the Mesopotamian civilization to the recent ones utilizing modern technology, farmers in arid regions are destined to be constantly troubled by this persistent problem of salinization (Fig. 2). Modern agriculture in arid regions is apparently confronted with the same threat which has partly caused the destruction of ancient civilizations..

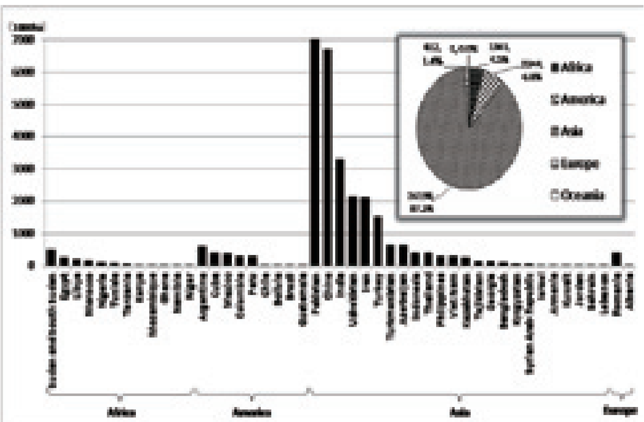

Fig. 2. Areas of irrigated farmlands damaged by salinization
Data : AQUASTAT main country database
(http://www.fao.org/nr/water/aquastat/dbase/index.stm)

Towards sustainable water use in agriculture

Global demand on staple food increases faster than population growth rate because the consumption of cereals per capita rises according to economic growth. On the other hand, investment for irrigation has gone dull in recent years and it has resulted in irrigated farmlands hitting the ceiling of expansion. One of the biggest reasons is that we have already developed every possible site suitable for a large scale irrigation system. However there are vast “untapped” water resources for irrigated agriculture in developing countries, particularly in Sub-Saharan Africa.

Water resources are not properties to be monopolized by specific individuals or enterprises but should be treated as common property or global public good for the use of the entire human race to be handed down to the next generations. We have to develop and use the local water resources carefully and in mutual cooperation under the recognition that these are global commons or public goods which should be protected for the sake of human beings’ sustainable co-existence with each other and with all the creatures on Earth.

Kazumi Yamaoka
Research Coordinator
Research Strategy Office, JIRCAS

Establishment of Extension Method for Vegetable Cultivation in the Dry Season Utilizing Limited Water Resources

Niger of West Africa is one of the poorest countries in the world where there are a lot of problems including lack of food security due to rapid population increase. Therefore, securing the food supply and increasing agricultural productivity are top priority issues for this country. Based on this background, a JIRCAS project was began in 2007.

Has the limited water resource been used sufficiently?

The water resources in this country are scarce, and the farmers cultivate the main crop by putting in all of their manpower as a priority task during the rainy season. Moreover, it is very difficult to use water in the dry season because many rivers are seasonal streams which appear only several days in each rainy season. On the other hand, 1,000 or more natural ponds exist in the whole country, and 175 of them retain water throughout the year according to the country's Water Resource Development Master Plan (1999).

JIRCAS focused its attention on these 175 natural ponds, and considered the possibility of promoting a better use for the existing water resource in dry season which had not been used effectively.

Why are vegetables not cultivated during the dry season?

Whenever the main harvest with their stock of food runs out and, despite imminent starvation, the farmers collect only from the trees and and eat grass until such time when the main crop could be harvested. Despite these circumstances, they still hesitate to cultivate vegetables using the natural ponds.

An interview survey which was aimed to clarify the restraining factors of vegetable cultivation in the dry season was conducted on-site in 37 villages. As outputs of this survey, restraining factors were identified in decreasing order of importance such as "Lack of controls against animal damage" wherein grown vegetables are eaten by the pastured animals; "Damage by blight and insects" before the vegetables are harvested; and "Difficulty in obtaining agricultural materials and equipment" when vegetable cultivation has already started.

How to promote vegetable cultivation during the dry season?

JIRCAS carried out an evaluation study focusing on the following three main activities in accordance with the theory that vegetable cultivation in the dry season will be promoted through the reduction of restraining factors.

In the "User Support Organization", management of agricultural materials, water use adjustment of the natural ponds and distribution of farmlands among the cultivating farmers, etc. were implemented (Fig. 1).

Fig. 1. Brainstorming together on vegetable cultivation in the dry season (Photo by: Jotaro Yasuhisa)

In "Agricultural Land Development Support", a suitable environment was created for the promotion of vegetable cultivation in the dry season and prevention of damage from pastured cattle, etc. in farmlands (Fig. 2).

Fig. 2. Installing a fence on their own to prevent damage to crops from pastured animals (Photo by: Haruyuki Dan)

In "Improvement of Farming Technology", trainings and researches were implemented concerning water-saving cultivation techniques and suitable irrigation methods were tested, etc. for the establishment of vegetable cultivation technology.

After the verification study was started, vegetables were cultivated actively on the study site. The cultivation area increased 2.3 times and the cultivated varieties doubled from seven to 14. Currently, the manual is being actively formulated with the cooperation of the government so that the achievements of this study would be more widely disseminated in Niger.

Haruyuki Dan
Rural Development Planning Division, JIRCAS

Applying Simulation Models to Analyze Environmental Pollution of River Basins in Tropical and Subtropical Islands

Many small islands dot the Pacific Ocean, Indian Ocean and Atlantic Ocean, such as the Marshall Islands, Maldives, and Trinidad and Tobago. It has been observed that these islands are vulnerable to natural threats which include rise in sea level caused by global warming and other environmental disadvantages inherent to island nations. Most of these developing small islands, which find it hard to retain sustainable development, are in tropical or subtropical regions. Tropical climate and soils are characterized by high intensity rainfalls, e.g. typhoons/hurricanes/cyclones and high soil erodibility, respectively. Extensive land uses in mountainous islands have caused serious soil erosion and massive damages to coral reef ecosystems in coastal areas. The Okinawa Islands and Sakishima Islands in Japan are facing similar problems caused by red soil runoff. Hence, there is a necessity to adopt effective countermeasures against soil erosion in agricultural lands.

JIRCAS has been studying the soil erosion problem shared among countries with mountainous islands and environmental pollution caused by nitrogen and phosphorus fertilizers in island nations, and has examined the appropriate management of agricultural lands to conserve rural environments. We selected the Todoroki River basin in Ishigaki Island, Okinawa Prefecture, Japan, as a case study basin, and commenced simulation modeling of the environmental pollution existing in the basin (Fig. 1).

Fig. 1. Downstream of the Todoroki River during a typhoon. Croplands on the right of this picture were saturated with water. Then the water overflowed into the river channel, until it reached the ocean. (Photo by Yoshiko Iizumi)

The total area of the Todoroki River basin is about 11 km^2. Its land uses consist mainly of sugarcane fields (36%), pastures (30%) and a few residential areas. The length of the river channel is 3.1 km. Because the length is short, every time the basin receives heavy rain, the flux and concentration of suspended solids in river water dramatically increase and rapidly flush out to the mouth (Fig. 2). Flux and water quality were measured in order to be able to evaluate the current situation of the river basin since 2006. Furthermore, simulation models were applied to the basin to clarify the causal relationship and outline structure of the watershed and material cycles, and to analyze the impacts of some land use changes.

In the Yaeyama region, including our study site, the most popular cultivation type of sugarcane is summer (August – October) planting. The harvesting season of this planting type is winter (January – March). After removing the crop biomass in winter, the soil surface of the fields is exposed to rainfall until the next cultivation. Thus, the quantity of soil runoff increases from winter to summer. According to the results, if the type of land use will be changed from sugarcane field to pasture, the amount of soil erosion will be decreased.

Fig. 2. View of the coast near the mouth of Todoroki River immediately during the aftermath of a typhoon. Large amounts of suspended solids were discharged from the river basin to the ocean. (Photo by Yoshiko Iizumi)

It is presumed that dissemination of the ratooning cultivation method of sugarcane with no-tillage will prove effective towards reducing the amount of soil erosion. In addition, based on our calculations, if filter strips like green belts are installed in the lower parts of the slopes in sugarcane fields, the concentration of suspended solids and nutrients in river water will be reduced whereas flux will not be affected significantly. It is suggested that the installation of green belts is also an effective countermeasure to improve the water environment.

These results have already been disseminated to leverage the efficient management of island environments.

Yoshiko Iizumi
Crop, Livestock and Environment Division, JIRCAS

Conservation of the Freshwater Lens in Marshall Islands

What is a freshwater lens?

The freshwater lens is defined as a freshwater zone, which floats in the shape of a lens on the aquifer layer, consisting of fresh groundwater on top of the denser seawater. It often develops in the aquifer of the limestone layer in the Caribbean Islands and the Pacific Ocean islands. The salination of the groundwater resources in atoll islands could rapidly become worse, and they depend so much on the freshwater lens as a water source, especially throughout the sea level rise and drought caused by global warming. Thus, it is necessary to conduct research and development for the conservation of this fragile groundwater resource.

JIRCAS has been conducting research on the movement and water quality of the freshwater lens in Laura, Majuro Atoll, the Republic of the Marshall Islands, since 2008 (Fig. 1).

Fig. 1. Aerial photo of Laura, Majuro Atoll, Republic of the Marshall Islands

Chronological changes of the Freshwater Lens in the Republic of the Marshall Islands

The shape of the freshwater lens in Laura was lenticular according to the results of the groundwater survey conducted by the United States Geological Survey (USGS), in 1985 (Fig. 2).

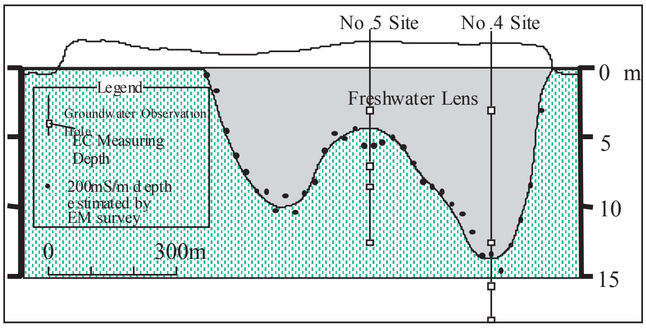

Fig. 2. Up-corning of the freshwater lens as observed in 2009 (Central cross-sectional view of the freshwater lens in Laura).

Then, they were able to confirm the existence of an up-corning of the freshwater lens through another groundwater survey conducted just after the extremely heavy drought, which happened in 1998, when the maximum number of consecutive dry days was 95. The inhabitants' only source of water during the long extended drought was the freshwater obtained through the seawater desalination plant and the groundwater drawn up in Laura. This intake caused the up-corning of salt water from the deep layer under and around the perimeter of the water intake facilities in Laura.

Present Situation of the Freshwater Lens

JIRCAS conducted an electro-magnetic survey, as joint research with the National Institute for Rural Engineering, to confirm the shape and the storage capacity of the present freshwater lens, so that we could estimate the depth of the boundary between the seawater and the freshwater lens. The figure below shows the cross-sectional view of the freshwater lens. The freshwater lens is thick at both ends, and the up-corning can be observed at the central part, and the overall shape is estimated to be almost the same as the one observed in 1998. The storage capacity of the freshwater lens is roughly calculated to be about 1.85 million tons.

Fragile Freshwater Lens

As a result of the water balance calculation, despite the average annual rainfall equivalent to about 1.8 times the storage capacity of the freshwater lens which has replenished the groundwater annually, the up-corning was still confirmed in 2009 in the same way. We were able to confirm that once the freshwater lens is salinized, it will pose a difficult task to recover it through the natural recharge despite the fact that a large amount of groundwater was re-supplied to it over a period of 10 years.

Further Development

The outputs of the research were made available to all government officials at the seminar. Thus, the importance of the conservation of the freshwater lens has been brought home to them and they already recognize it as an urgent issue. It is necessary for the sustainable use of groundwater, not only to establish a stable groundwater intake method, but also to build a suitable and efficient groundwater management system to be maintained by the Government of the Republic of the Marshall Islands.

Kazuhisa Koda
Rural Development Division, JIRCAS

Effective Use of Wells in the Grasslands of Mongolia

It's common knowledge that livestock like cattle, goats or sheep (Cattle, goats, sheep, horses and camels are Mongolia's five most important livestock.) are usually pastured in vast grasslands in Mongolia. The herders find grass by moving around the vast grasslands, taking groups of livestock around for grazing every season in summer, autumn and winter, while leading a nomadic life. JIRCAS was able to determine that there were instances of cattle moving nearly 20 km in distance in just one day in search of pasture during summer in the Mongolian steppe grasslands.

For such nomadic grazing, same as grass for feed, an indispensable necessity is drinking water for the livestock. In addition to cattle gathering at watering places with available surface water, there are dug wells which are resorted to for water in the vast grasslands in Mongolia, where there are many regions in which the amount of rainfall doesn't come up to as much as 150 mm a year. In fact, whenever water from a well is drawn out, even if it's barely detectable from far away, thirsty cattle will instinctively congregate there (Fig. 1).

Fig. 1. Animals gathering near a well in a grassland in Uvurkhangai Province, Mongolia (Photo by Takeshi Matsumoto)

Despite the importance of wells, there aren't many which are managed efficiently in the grasslands. When it rains on the vast grasslands, sand flows in with the water and enters into low-lying wells. Often, stones are likewise thrown into the wells to break the ice each time the well water becomes frozen. Wells are gradually buried because of these. Likewise, the outdated machines of the rotary draw well system which were installed with the aid of the Soviets during the Socialist era can't take up water any more. Because it isn't possible to keep cattle at the grasslands with no available water for livestock use and since cattle will only concentrate in grasslands with water, it will lead to overgrazing. Thus, JIRCAS decided that it is necessary to manage wells in the areas with no other source of water and maximize their use in order to preserve the Mongolian grasslands.

The following are the reasons pointed out why wells couldn't be managed efficiently: (1) Since there is no fixed assignment on who would manage the wells, the responsibility for well management is vague; (2) Herders lack techniques or skills for repairing or managing wells; and (3) They don't have enough capital to repair/manage wells. If these problems are resolved, it's highly expected that the wells will become more adequately managed.

To resolve these issues, JIRCAS created the following approach with the cooperation of the local herders who use the wells and with the support of the local administration officials: (1) Herders who regularly use a well together has to form a group which will be responsible for managing their common well; (2) A "Well repair team" will be organized in each "bag" (the smallest unit of the local administration) from among the member herders to manage/repair the wells; (3) Every herder who regularly uses the well will donate one live sheep as a fixed contribution to form the "Sheep Fund" which will ensure available capital for managing/repairing the wells.

JIRCAS researchers actually conducted test repairs of the wells while applying this system and was able to validate its effectivity. Simultaneously, a repair technique was also shared by an engineer of the local administration with the "Well repair team".

This system has been accepted by the local herders as the most effective and simple way to manage and repair wells self-sufficiently on their own. By 2011, 12 wells had already been repaired using this system, which is being disseminated around at present as technology transfer.

We are expecting the Mongolian grasslands to be better preserved if the wells will be smoothly managed and maintained in such a manner.

Takeshi Matsumoto
Rural Development Division, JIRCAS

Rainfed Agriculture Project

Rainfed agriculture is agriculture which depends solely on rainfall. Generally, it comprises approximately 60% of all existing arable and cultivated fields and the yield per unit is only half of irrigated agriculture. We tried to achieve the following three objectives: “Developing water resources”, “Improving water use efficiency”, and “Formulating guidelines for diversified agriculture in this project.”

Rainfed agriculture is complicated. We became aware that rice-based agriculture is a common aspect of agriculture in Indochina, and then we categorized it into three categories: lowland, upland and mountainous areas. We set up study sites in each area and carried on site-based multidisciplinary studies.

For example in Thailand, many farm ponds have been designed for farmers; however, these have not been used efficiently. We analyzed these ponds using satellite data and digital elevation maps. The results show that most of the ponds face problems such as lack of water harvesting areas or these are located at inconvenient locations. On the other hand, there is “Fai”, a traditional communal utilization system which has a weir located at the bottom of the valley. It is supposed to provide water at the bottom of the valley to upper paddy fields but instead the water rapidly flows away. We estimated its efficiency using a hydrological model. It has been found that farmers could deliver half the amount of all the farm pond water in the watershed into their paddy fields if repair is done to the “Fai” system (Fig. 1).

As far as improving water use efficiency, water-saving vegetable cultivation methods have been developed through farmer participatory approach. It is a way of developing technologies as follows: Researchers first show farmers the incomplete technology samples and then the farmers complete these by selecting technologies suitable for their own use. Since there is stored soil moisture even if it looks desert-like on the surface, watering can be decreased to twice a day once a week or with zero irrigation (during fair conditions) by merely using the soil moisture.

Fig. 1. Use of ponds in Thailand (Photo by Masato Oda)

Finally, together with counterpart researchers, we have successfully formulated guidelines which contain the above information for diversified rainfed agriculture.

Masato Oda
Crop, Livestock and Environment Division
JIRCAS

Water-saving Rice Cultivation: Alternate Wetting and Drying (AWD)

There are forecasts that the situation of water shortages will become more serious in the agricultural sector due to the increasing demand for agricultural products and for water from non-agricultural sectors. Rice, which requires water 2-3 times more than other cereals for its production, is no exception.

In this context, the Water-saving Project (one of the projects funded by the Japanese Government based in the International Rice Research Institute (IRRI), Philippines) was carried out for five years from 2005 to 2010. One of the significant results of the project that aimed to develop suitable breeding materials for water-saving cultivation, to improve water-saving technologies, and to evaluate their effects on the environment was the finding that the AWD water-saving technology has real potential to reduce the global warming impact of paddy fields to one-third (1/3) of the conventional continuously-flooded field water management.

The water-saving technology called AWD (alternate wetting and drying; Fig. 1), a sort of intermittent irrigation technology under which the fields are re-irrigated when soil moisture reaches down to a criterion value, has been recommended by IRRI as a technology that makes water saving and high yield compatible. This technology has been disseminated in the Philippines, China, Vietnam, Bangladesh, India, et al. as a technology that's proven to reduce irrigation water use by 15-30%.

Fig. 1. AWD (alternate wetting and drying) field plots under water stress (Photo by Yasukazu Hosen)

Though the effect of its water-saving environment on the global warming potential of paddy fields was not clear at first, we found that AWD can reduce the negative effect down to 1/3, compared to that under continuous flooding, taking both the reduction of methane emissions and the increase of nitrous oxide emissions into account (Fig. 2). We also found that the emissions of nitrous oxide can be reduced to the level of those under continuous flooding by being submerged for several days after N application and that the effect of earlier straw incorporation on the reduction of methane emissions is also as effective under AWD conditions as under non-AWD conditions.

Fig. 2. The system that we used for monitoring greenhouse gas fluxes; using these box-shaped gas sample collectors, we continuously and automatically collected and analyzed gas samples. (Photo by Yasukazu Hosen)

How about its effect on the soil? It is well known that the submerged condition of rice paddies inhibits the decomposition of soil organic matters and contributes toward keeping soil fertility. The possible decreased rate of soil organic matters under AWD management, which provides less moisture during cropping periods as compared with continuous flooding conditions, is an important point to discuss on the sustainability of farmlands. As we closely monitored the field soils in which we had carried out a 4-year (8-season) continuous cropping experiment, we discovered that the 4-year continuous cropping did not significantly affect the contents of major types of soil organic carbon and nitrogen.

These results are being utilized to develop a method for model analysis through which we can estimate the potential effects of AWD application in different environments and wider areas. These are also being applied to farmers' rice paddies in the Mekong Delta region.

Yasukazu Hosen
Crop, Livestock and Environment Division, JIRCAS

JIRCAS Newsletter
Japan International Research Center for Agricultural Sciences (JIRCAS)
March 2012-No.63
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