Water Resources in relation to Major Agro-Environmental Issues in Japan

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Abstract

Although Japan is well known as an industrialized country rather than an agricultural one, agriculture is treated as a very important sector for its cultural and environmental perspectives. Only 15% of Japan's land is suitable for cultivation, but the agricultural economy is highly subsidized and protected. With per unit area crop yields among the highest in the world, agriculture sector still dominates the major part of water use (65%) in Japan followed by domestic and industrial uses (20% and 15% respectively). Like many other monsoon Asian countries, rice is the staple food in Japan, and paddy fields and terraces are often referred to as the country's cultural and environmental indicators. This paper outlines the condition of water resources and their relations to some major agro-environmental issues in Japan.

Keywords: water use, water pollution, surface runoff, agro-environment, agro-ecosystem.

INTRODUCTION

Agriculture plays a significant role in the world in achieving sustainable development because of its importance to food supply and the social structure of rural areas, as well as its impact on nature and the environment. Depending on the region/country, these different aspects are weighted differently. As for Japan, the country's agriculture, although a tiny but often termed as an outstanding contributing sector to the country's economy (1.5% of GDP) , is characterized by high production and secured subsidies because of its socio-cultural background and environmental characteristics. The relatively wet climate dominated by monsoon provides the country with considerable freshwater supplies. The general reliability of the precipitation pattern, coupled with Japan's extensive network of rivers is used for irrigation, make possible extensive wet-rice cultivation. For the last two decades, the country has been paying much attention for its water resource management as well as on agriculture and environmental aspects. However, some natural and man-made agro-environmental disasters associated with water (use and quality), land (use and management), agro-ecosystem, agro-biodiversity, global warming etc. still remain as major problems to be solved. This paper reviews some major agro-environmental issues in relation to water resources management in Japan. The main objectives of the paper are to:

- ○ introduce the present status of water resources, such as precipitation, rivers & lakes, water withdrawal rate in Japan;
- ○ Review the linkages between water and some major agro-environmental issues, such as non point source pollution, soil erosion, ecosystem and biodiversity;
- ○ Highlight a case study in southern part of Japan;
- ○ Outline limitations and analyze future trends of water resources and their relation to agro-environment ecosystem from local perspective.

The first half of the text of this review paper is composed of the information and data available in recent publications, while the second half describes a case study and analytical comments.

CLIMATE AND GEOGRAPHICAL FACTORS

Japan consists of a great string of islands in a northeast-southwest arc that stretches for approximately 2,400 km through the western Pacific Ocean. The country has a total land area of 377,887 square km. Nearly this entire area is taken up by the country's four main islands; from north to south these are Hokkaido, Honshu, Shikoku, and Kyushu. Honshu is the largest of the four, followed in size by Hokkaido, Kyushu, and Shikoku. In addition, there are numerous smaller islands, the major groups of which are the Ryukyu (Nansei) Islands (including the island of Okinawa) to the south and west of Kyushu and the Izu, Bonin (Ogasawara), and Volcano (Kazan) islands to the south and east of central Honshu. About 70-80% of the country is mountainous. The mean annual precipitation is 1,740 mm (approx.), ranging from 800 mm (approx.) in the north of Hokkaido Island to 3,600 mm (approx.) in the south of the country. Most parts of Japan are within the North Temperate Zone with four seasons a year. Though Japan would appear to have plentiful water resources, it is so densely populated that the annual amount of per capita rainwater is only 5,100 m³ which is about one-fourth of the world annual average(22,000 m³/capita). Moreover, this amount varies significantly with area and time.

WATER RESOURCES IN JAPAN

Rivers, Lakes and Reservoirs: In Japan, there are more than 2,700 river basins. Among them, 109 rivers are designated as being managed by the central government in principle because of their major importance to the economy and to the protection of the environment. The catchment area of these Class A rivers covers about 239,900 km². Class B rivers consist of the other rivers which are managed at local level (prefecture government level). Average surface water resources are estimated at 420 km³/year. There are 247 freshwater aquifers underlying a total area of 69,130 km². The renewable potential of groundwater resources is estimated at about 27 km³/year, though because of the steep slopes, a significant part (estimated at 17 km³/year) probably returns to the river system. Where land subsidence, saline intrusion and excessive lowering of the water table have occurred, groundwater use has been restricted to a safe yield by applying legal regulations and ordinances to critical areas. The total annual renewable water resources are estimated at 430 km³/year.

More than 600 lakes are scattered among the seaside districts and the volcanic zones. The major lakes in the country are:

- Biwa lake, which lies in the inland basin near Kyoto in central-west Honshu with an area of 674 km² and a water volume of 27.5 km³;
- Kasumigaura lake, which is close to the mouth of the Tone-gawain with an area of 220 km² and a water volume of 0.848 km³;
- Inawashiro lake, which is a lake created after a volcanic eruption in northwest Honshu with an area of 104.8 km² and a water volume of 3.86 km³.

The history of dams and reservoirs in Japan dates back many centuries, and a number of ancient earthen dams are still used for paddy irrigation. Since the 1920s, technological advances have led to the construction of dams and weirs with modern designs, and these have contributed mainly to irrigation development and hydropower generation. The construction of large-scale multipurpose dams including flood control began in the 1950s to meet increasing water demand for municipal and industrial use as well as irrigation. In 1993, there were 2,556 dams over 15 m high in service for water supply, hydropower generation and flood control, for a total effective storage capacity of 16.5 km³. In addition, 587 dams under construction at that time were planned to provide 7.7km³. The total storage capacity of all these dams is about 29 km³. A 1990 survey showed that another 4.8 km³ were provided by small dams. In 1996, the installed capacity of all power plants in operation was 226,994 MW, of which 21,171 MW or 19 percent was hydropower.

Water Use in Agriculture : Agriculture holds the major part of water use in Japan (65% of the total water withdrawal). Water for flooded rice paddy fields and fish culture comprises most of Japan's agricultural water use. Water use for agriculture has recently been flat nationwide, with a slight decrease in rice paddy irrigation offset by an increase in irrigation for other crops. Irrigation of rice paddies, which takes up the largest portion of agricultural water usage, dropped only slightly, in spite of decreased rice paddy acreage, partly because of the increased water use per unit area in paddies and the lower rate of recycling due to the digging of separate canals for irrigation and drainage. Demand for water in rice paddies is seen from mid-April through September, with peaks during tillage before the crop is transplanted, and in the season after midsummer drainage. Water use during tillage in particular, has risen recently. There is a small demand for water during seasons other than the ones mentioned above, for secondary crop farming and crop rotation. Irrigation for other types of crops is expected to continue to increase because the area land with access to irrigation is increasing and in many cases, agricultural chemicals and fertilizers are mixed with the water that is used to irrigate these fields. The supply or water to green-houses particularly, has increased steadily in recent years, and their growing popularity has increased the demand for water in winter.

Water usage in livestock farming is expected to continue to increase because of the growth in the number of livestock. Aquaculture is also growing, although it accounts for a small portion of all agricultural land. Water culture, which is a form of liquid culture, is the main form of liquid culture in terms total area. Irrigation channels have traditionally served several functions in agricultural areas, such as supplying water to wash crops and agricultural machinery, fire protection and preservation of the rural environment. To maintain and promote the use of such functions, various approaches are being taken in the improvement of irrigation channels, including construction of recreational areas, with trees and shrubs planted along irrigation channels.

MAJOR ISSUES CONCERNING WATER AND AGRO ENVIRONMENT

As it could be understood from the above information also, to maintain the standard of quality, to secure the required quantity, and to manage such a vast amount of fresh water used in agricultural purposes in sustainable ways are very important to maintain different related agro-environmental components.

In this section, the author will focus and discuss some major agro-environmental problems associated with water resource management, namely non point source pollution from agricultural fields, rainfall erosion and its effect on aquatic ecosystem and biodiversity in south part of the country.

Non Point Source Pollution: Water quality is a major environmental issue. Japan's aquatic environment has improved significantly over the last few decades, as industrial water pollution was sharply curtailed. However, the environmental quality standards for organic water pollution are still not being met in about 30% of Japan's total water area. Pollution from non point sources is one of the single largest remaining sources of water quality impairments in Japan. Agriculture is a major source of several non point source pollutants including nutrients, sediment, pesticides, and salts that deteriorate the water quality in rivers and oceans, cause eutrophication in lakes and reservoirs.

Although in Japan, there is no general law encompassing all aspects of water resources management, however, specific aspects related to water resources management are regulated by legislations such as Water Pollution Control Law (updated as 1of 1996), the River law (updated as of 1997), the Land Improvement Law (updated as of 2001), the Water Resources Development Law (updated as of 1983) etc. Such laws have been effective to solve a specific land and water pollution problem. But when different types of pollutants come from different non specific sites especially where farmers and non-farmers living alongside each other in agricultural and rural communities, it becomes a hard job to solve, practically.

Scientists in Japan have recently suggested approaches and models for proper watershed management to reduce the non point effluents to the rivers and lakes. Kato et al (2004) assessed the non point outflow loads to Kasumigaura lake for the past 10 years, and developed a material cycle evaluating system that could reduce the total nitrogen load to the lake up to 40%. Funakawa et al (2004) developed another water quality model based on the study of non point effluents to Biwa lake and Noda Lagoon. Tada et al (2006) reviewed different models to estimate the effluent loads from watershed, and focused on the uncertainties of hindered non point sources. According to the water quality researchers in Japan including Tada (2006), a model based official program, for example, the TMDL (Total Daily Maximum Load) program in USA, would be effective to reduce the effluents from watersheds to the water basins.

Soil Erosion: The outflow of topsoil from the farmlands mainly due to water and wind are termed as soil erosion in agriculture. In Japan, soil erosion has not been a serious problem for the last few decades except some parts of the country. Northern parts including Hokkaido and Northeast region (Tohoku region) are little vulnerable to wind erosion followed by water erosion. However, since the country has not a distinct dry season and most of the farmlands are well reclaimed, wind erosion in Japan is an issue of merely local importance. Rather, water erosion caused by rainfall has been a long time problem (since 1972) in the south part (Okinawa Island) of Japan. The island's annual rainfall amounts much higher than the country's average annual rainfall. Moreover, farmland soils (Kunigami Maji, Shimajiri Maji, Kutcha etc.) are mostly clayey, and so vulnerable to erosion. In addition, pineapple and sugarcane are the common crops cultivated as the main cash crops in the island. Both these cropping fields are, by their nature (ridged and furrowed), susceptible to erosion. In past years, many researches (Onaga et al 1978-1984, Gibo et al 1984) have been carried out that encouraged the local government to introduce a policy named 'Red soil pollution monitoring' in 1985. Till today, the monitoring system is in progress, but achieved a little in practice. Further research works were done by researchers (Onaga et al 1990, Gibo et al 1994, Kusaka et al 1998, Yoshinaga et al 2000) to find out different technologies to prevent soil erosion from farmlands. Researches are still going on this subject but if we look at the history and the present status of red soil erosion in Okinawa, researchers' suggestions have not always welcomed by the local farmers because of many locally oriented socio-cultural and traditional backgrounds (Matsumoto and Roy, 2004). The situation reminds the necessity of doing more researches that could be accepted by the local farmers. In other words, while planning a research, a pre-feasibility study is a must where local farmers' opinion gets priority.

Agro-Ecosystem and Biodiversity: Especially, in Japan, conservation of biodiversity and ecosystems in agriculture has been an important issue in agricultural and environmental policy since 1999, when a changed agricultural foundation law stimulated progress by the Japanese government and EU (European Union). Rice paddy fields ecosystem is treated as the most important agro-ecosystem and biodiversity indicator in Japan. According to the literature before, about 2,000 species of plants and animals associated with rice paddy fields have been recorded in Japan (Hidaka 1998). This biodiversity in species richness can be regarded as a general characteristic in the rice paddy ecosystem. Kobayashi et al (1973) examined in detail the biodiversity of arthropods using sweeping methods in rice paddies of several sites of Tokushima Prefecture in the late 1950s. More than 450 species of insects, spiders, and mites were recorded. Kasahara (1947) examined a list of rice paddy weed specimens in 25 prefectures over Japan and recorded 174 plant species. However, nowadays, if we had a chance to examine arthropod fauna in the same fields, it might be difficult to collect a closed number of species in rice paddies such as in the 1950s (Hidaka 2004). Such a decreasing tendency of different natural habitats and species in the rice field ecosystem in Japan is apparently derived from rapid urbanization, steady production level maintenance etc.

ENVIRONMENTAL DEGRADATION BY SURFACE RUNOFF - A Case Study in Okinawa Island –

Okinawa is Japan's southernmost prefecture and consists of hundreds of islands in a chain over 1,000 km long where Okinawa Island is the largest one. Okinawa has a humid subtropical climate, with an annual rainfall ranging from 2,000 to 2,500mm. The rainfall erosivity is very high and the dominant soils (commonly termed as red soil) are highly erodible that causes the loss of valuable topsoil from the farmlands as well as making the ocean water polluted. Most of the red soil particles (mostly silt and clay) carried to the sea by rivers and or canals are deposited on semi enclosed reef moats adjacent to the coast, and often the red soil is repetitively stirred up by turbulence induced by typhoons and monsoons. The water then becomes cloudy and the soil is distributed over the reefs and cause decay. The deterioration of the coral reef along with other aquatic species environment as a result of eutrophication and pollution from increasing sedimentation has already been reported. Coral reefs, which offer shelter to small reef animals in their three-dimensional spaces, are said to hold the largest number of species per unit area on earth. So, when corals die out and the three-dimensional space decreases, eventually the numbers of fish and other organisms also decrease. The central and local government offices have introduced several techniques such as establishment of green belt, infiltration tank, sedimentation tank, underground drainage etc. and uses of different soil improvers, coagulants, mulches etc., as well as evaluation and monitoring system for measuring red soil outflow. However, things are not going satisfactorily as expected. The reason is that a lot of local factors other than technological aspects are involved in the red soil erosion process in Okinawa. But one thing what farmers and policy makers agree is that – 'not to let the soil go out of the fields is the best way to overcome the situation'.

For the last few years, the author has been carrying out field surveys and experiments in some parts in Okinawa to find out some technologies that could be accepted by the local farmers. In this section, the author will introduce a case study result to improve the hydraulic conductivity of red soil while treated with different waste materials. As also mentioned in the above section of soil erosion, most of the Okinawa's farmland soils are clayey and silty with poor hydraulic conductivity. When raindrops strike the surface, the surface soil creates a crust which also hampers the infiltration. As a result, surface runoff takes away the topsoil out of the field. Therefore, to increase the infiltration rate would help to decrease the surface runoff. A preliminary survey was carried out to get an idea about the technology extension among the farmers in Okinawa. The survey result helped the author and his research group to make a decision to grasp the present condition of conservation works in Okinawa's farmlands and search for possible locally fitted materials. In most of the sugarcane and pineapple fields, farmers use the plant residues as organic mulch. This practice helps to maintain the soil moisture as well as to minimize the raindrop effect to some extent. But when heavy and concentrated rainfall occurs, the mulching materials themselves also washed out from the fields. Therefore, while planning the research and experiments, the author targeted to find out more efficient ways to use the plant residues so that it could be a contributing factor to improve the soil structure (like humus) that accelerates infiltration rate. Discarded fired potteries, a common traditional item, were also used as experimental materials. The materials were processed in the author's lab. The processed materials were then mixed in different ratios with the sampled red soil (Kunigami Maji soil), and put them (only sugarcane residue-mixed samples) in an artificial atmospheric chamber (**Fig. 1**). The temperature and the humidity of the artificial atmospheric chamber were fixed to that of Okinawa's condition. In short, the materials (sugarcane plant residues and fired potteries) were grinded by a small grinder, and then mixed them with different ratios (soil: mixed material). Then the mixed soil samples were placed in the artificial chamber for 1 month, 2 months, 3 months and 4 months. Observations were carried out regularly and column tests (**Fig. 2**) were performed by using the treated soil samples. The changes in organic matter content (%), thickness of crust (mm), porosity (%), soil aggregation, and hydraulic conductivity (cm/s) were measured for each soil sample. From the result, the best condition to use the local materials was determined. The results (**Fig. 3 and 4, Table 1 and 2**) of the experiments indicate that a small amount of grinded sugarcane plant residues mixed with the red soil could increase the infiltration rate that could result a decrease of surface runoff. Such a treatment can easily be performed under natural condition in any Okinawa's farmland just like making a hole at one corner of the field and put the grinded residues inside it. It is noted here that while applying the result to the practical farmlands in Okinawa, a machine to perform the grinding operation in large scale has to be designed.

CONCLUSIONS

When many of the Asian countries are still struggling to provide the basic needs to their people, factors such as population, poverty, education, technology are not issues in Japan. The Japanese Government and its Ministries are doing a lot of research and extension works within the country and providing various materials, incentives and programs to help people understand the current state of the agro-environment and water resource. Japan is one of the most leading countries in the world now to handle the environment and water problems. The country hosted the Ministerial Conference, on the occasion of the 3rd World Water Forum, in 2003. 'Kyoto Protocol' was highly appraised by the environment lovers throughout the world. Even after that, the speed to eradicate the existing and remaining tasks as some mentioned in this review paper is not notably rapid as and when compared with the same to the industrialization and economic development of the country. Why? As to the author's opinion, many other factors such as socio-cultural, traditional, after-effects of modernization etc. are correlated with the resource management and environmental aspects. Some of them are concluded here.

Recently (2003), Japan Government adopted a policy to establish a sound hydrological cycle via various fields such as forests, agricultural land, rivers, water-supply and sewerage systems, etc. Five ministries (Ministry of Health; Ministry of Agriculture; Ministry of Economy; Ministry of Land, and Ministry of Environment) have been engaging in consultative meetings in order to share related information and promote deliberation on comprehensive measures. The Guideline for Establishment of Sound Water Cycle (2003) has been developed to clarify the basic direction of identifying the factors that cause water-related issues by evaluating the overall water cycle, and dealing with the problem. The policy is undoubtedly a good step. But, as also suggested by many researchers in Japan, still no efficient model or program like TMDL (Total Maximum Daily Load) program (in USA) was included in the government policies and laws that could assess and prevent the non point effluents from any particular spot more efficiently.

As for soil erosion problem in Okinawa, less pre-feasibility studies were carried out on the local farmers' attitude before introducing technologies to prevent farmlands from soil loss. Agriculture and farming works are labor-intensive. In Okinawa, most of the farmers prefer to produce sugarcanes and pineapples because the lands are suitable for that crops as well as the farming operations, land management are less labor intensive. In addition, no other major alternative crops have been proved more economically feasible there. Replacing the existing traditional farming system/crops by only a technologically-better way is mostly impractical in Okinawa. Therefore, to extend any new method to the farmers, locally fitted research works should be given priority.

There are many reports and media-news on the recent food habit change of young Japanese. Western foods, fast-foods that not essentially use rice materials are getting popular and the consumption of Japanese rice is getting low gradually. Moreover, young generation is losing fascination to agricultural works. Naturally, the paddy field area is showing a declining tendency in recent years. Labor shortage is so acute that Japanese Government is considering to import foreign labors for agricultural works (Asia Times, Dec 3, 2003). In Japan, where rice paddy field is the main indicator of agro-environment and ecosystem, paddy-less Japan will bring many new environmental problems.

Besides, there are some other problems associated with water and agro-environment still remain to be solved, such as construction of dams, land consolidation, river head works, global warming etc. Whenever any of these technical matters becomes a problem in any locality, and focused in the mass media, rather than technical, many socio-cultural, political and traditional factors are in the headlines. So, why not such factors should be considered at the basic stage while planning and designing a technological approach?

Finally, it is fact that every short of eco-environmental problems associated with water and agriculture cannot be eradicated completely (100%) since the total ecosystem is incorporated with many known and unknown sub eco-systems and factors. But in a highly developed country like Japan where government and people are careful, resource management and maintenance of eco-environment can be achieved to the best.

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Figures and Tables in this page show the experiment results as stated in the section:
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Fig.1 Artificial Atmospheric Chamber

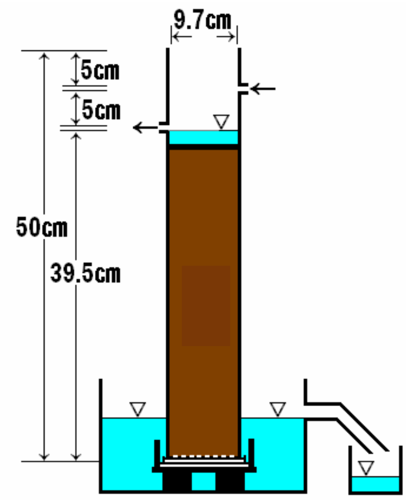

Fig.2 Hydraulic Conductivity Test Apparatus

Table 1 Organic Matter in Treated Soil

Sugarcane residues	OMC (%)
2 months treatment	6.62
3 months treatment	6.63
4 months treatment	7.56

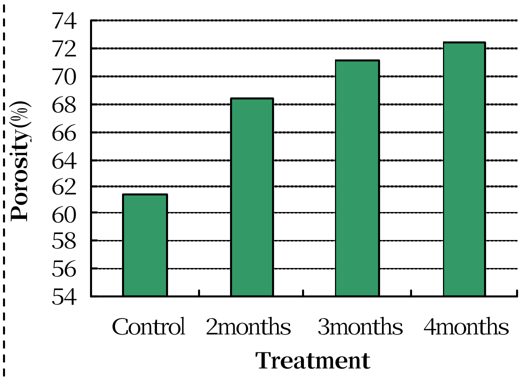

Fig.3 Comparison of Porosity (%)

Table 2 Crust Formation in Each Sample

Sample	Thickness(mm)
Control	3.4
Sugarcane(non-treated)	2.5
Sugarcane(2 months treated)	1.5
Sugarcane(3 months treated)	1.6
Sugarcane(4 months treated)	1.5
Fired potteries (0.2~2mm)	2.1
Fired potteries (2~4mm)	2.5

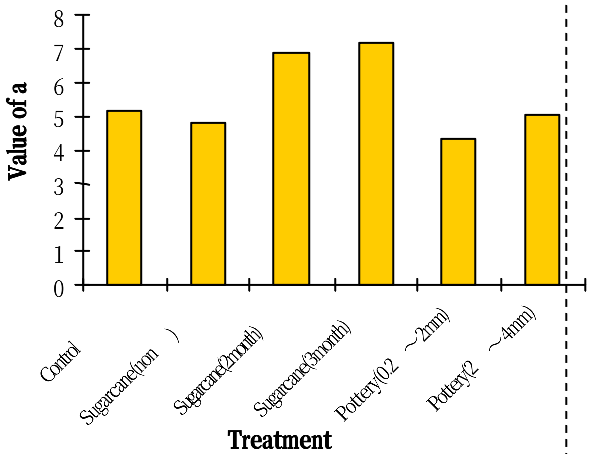

Fig.4 Comparison of Hydraulic Conductivity(cm/s)
* when, hydraulic conductivity $k = a \times 10^{-4}$ (Darcy's Law)