

# **Horizontal Aspects of Agricultural Water Use in Water-rich Monsoon Areas: Managing Information of Sectoral Demand in the Japanese Case**

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## **Executive summary**

Many Asian countries have expanded paddy field rice production depending on warmer climates and abundant water, but water scarcity in these countries emerges in the form of brief dry spells. The paper illustrates the generic features of water use in paddy field agriculture and suggests a possible direction of water resource management considering the Japanese case. Knowledge and information required for the better management are also focused on.

Other than capital investments and the renewal of old facilities for a more secured water supply to cope with annual fluctuations of available water resources, reallocation of water and water rights among agricultural, industrial and municipal sectors can play an important role in the Japanese case. We indicated two important aspects for better management: (1) knowledge of the structure and price responsiveness of residential water demand is required for the municipal sector to control the water demand in a socially acceptable manner, and (2) how much water becomes available to other sectors when the agricultural sector reduces irrigation water use should be the basic information for the reallocation of water and water rights among sectors. The second aspect is particularly important for the countries that are located in monsoon districts and agriculture which is dominated by irrigation agriculture of paddy fields.

Better information on the future prospect of the precipitation pattern under climate change is also required to secure the stable water supply in the country.

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## **1. Introduction**

Historically, many Asian countries have achieved higher carrying capacities by paddy field rice production depending on warmer climates and abundant water, but water scarcity in these countries emerges in the form of brief dry spells. The investments for water storage and irrigation facilities in paddy field could lessen the risk of water shortage during dry spells and secure the stable exploitation of water from fluctuated river flows. The collective use of irrigation water and a longer history of property rights establishment for water would be other outstanding features in Asian countries. The former brings out the public nature of water in society. The latter suggests that society should make a successful consensus to deal with the emerging demand not only due to

the agricultural development but also from residential and industrial sectors according to the economic growth. In addition, the agriculture based on paddy fields would minimize the contradiction to the natural habitat, and even enhance it through multifunctionality.

The paper, focusing on the aspects of knowledge and information in this field, illustrates the Japanese case and suggests a possible direction of water resource management, which should be economically efficient and socially acceptable, to create the stable sources and to allocate available water among sectors in the condition that property rights (water rights) have been established already in its long history of customs formulation and legislations.

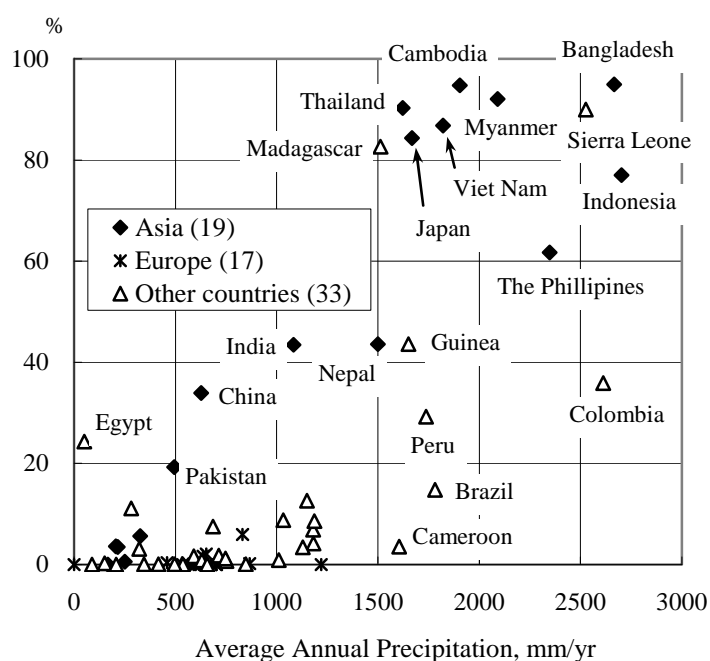
Because the rainfall in Japan on average, although it fluctuates considerably throughout the year, seems to be sufficient compared to the water demand, newly constructed infrastructures have created stable water resources fulfilling emerging demand in the rapid economic growth since the Meiji Era. The basic framework of Japanese water management is: (1) in the normal period of normal precipitation an independent and autonomous authority of each sector (agriculture, industry, municipality or power generation) provides water in the territory based on its water rights, (2) in the period of water shortage a temporal reallocation of water is voluntarily arranged under public consultation, and (3) when and where the potential discrepancy between water rights and actual demand among sectors in the region is recognized under periodical reviews, a permanent reallocation, i.e., reallocation of the water rights, is arranged by governmental consultations.

In the latter two cases the knowledge and information in each sector have an essential role in allocating water or water rights. The proper knowledge and information of (1) the acceptable level of water saving in agricultural and industrial sectors taking into consideration both technical and economic constraints, (2) characteristics in the demand for residential water such as price responsiveness (price elasticity) and its relationship with the tariff structure, the level of consumption by 'income class' and so forth, (3) future prospects of water demand from each sector particularly in the case of water rights arrangements, and (4) future prospects of precipitation patterns, would be needed by basin. These are still being gathered and the exchange of them among sectors should be more effective and transparent. The paper focuses on the generic features in water demand in agricultural and residential sectors.

## **2. Water resource and agriculture in the monsoon Asia: General features**

Looking at the map of annual mean precipitation during the 1979-2001 in Adler et al. (2003, p.1154), we can clearly find that most countries in the eastern part of Asia are endowed with the higher precipitation well above 1,000 millimeters per year (mm/yr). This area including the coastal part of China and the eastern part of India, i.e., the monsoon Asia, carries more than 1.5 billion people [1](#)). The abundant water in accordance with warmer climates enables paddy field agriculture and achieving higher carrying capacities (Figure 1).

**Figure 1. Share of rice harvest in cereal production and average rainfalls**



Source: FAOSTAT & AQUASTAT, FAO. Precipitation in China from MAFF, Japan.

Note: Countries of crop harvest more than 1 million ha in 2007. The Pearson's correlation coefficient is 0.78.

Most of the rainfall runs off to the sea from these countries and in this sense the water itself does not necessarily seem to restrict agricultural production, but that is obviously not the case in reality. Firstly a proper investment in land infrastructure is essential for effective use of water, and secondly the rainfall fluctuates considerably under the monsoon climate both in season and in short-term. According to the statistics there tends to be a higher precipitation in accordance with a stronger seasonal fluctuation 2). Due to the seasonal fluctuation it is often the case that the 'rain fed' paddy can only grow rice once a year during the wet season.

However, the most serious risk in agricultural production heavily dependent on rainfall takes place due to unexpected short-term fluctuations. This is paradoxical that the farmers cultivating paddy field counting on the abundant water easily face serious risk when there are abnormally dry spells than those in arid and semi-arid areas who depend more on ground water and stable flow from rivers and cultivating water saving crops other than rice (Yamaoka, 2006).

Even if the rainfall well exceeds the demand for water, *on average*, water is obviously a scarce resource in the following three contexts focusing mainly on the surface water classified as a renewable resource 3).

**i) Short run in the period of abundant water**

Other resources which are not free such as dykes, canals and other irrigation facilities are required for the actual use of water. That is the case when any economic activity utilizing

water takes place. The fact that end users are charged for water does not imply that the scarcity rent of water as a natural resource is generated. If water is not scarce, the demand for water from any sector in the short run is decided at the point where the marginal benefit of end use and the marginal cost of water supply, which consists only of the O&M cost based on the given social infrastructures, are equalized. Even in cases where some property rights for water are established in society, no exchange of water among sectors will be expected, or required for economic efficiency (Figure 2).

#### **ii) Seasonal fluctuation in the precipitation**

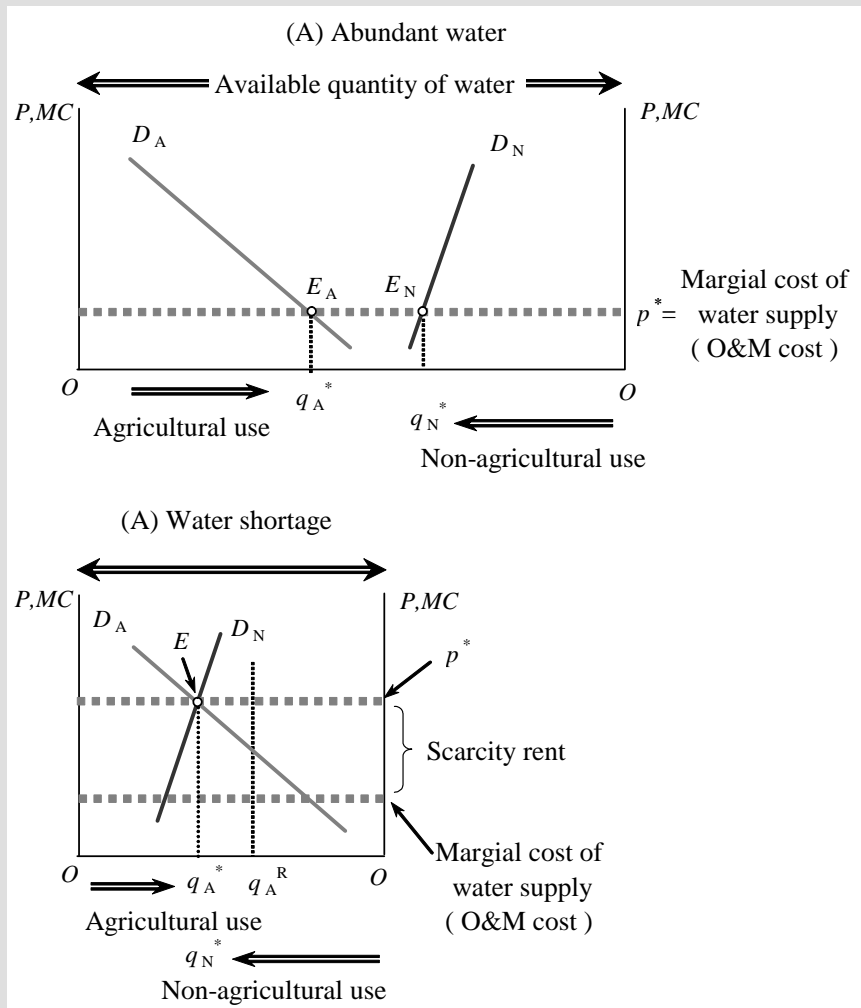
As water is not abundant during the dry season, economic activities requiring vast amounts of water are restricted, however the agricultural activities in particular would have adapted to the normal rainfall pattern throughout its long history. This kind of restriction, however, could be released to a larger extent by the capital investments of storage such as ponds, reservoirs or dams, or irrigation facilities to withdraw water from rivers of stable flows. Provided that the surplus water is stored in the rainy season or the river flows are enough not to disturb other demand, we could recognize that the scarcity of water in the short run diminishes to a large extent and is embedded into the capital investment. Historically, agriculture has been the primary target to be invested in since the beginning of the economic development. In addition to the irrigation infrastructures for an efficient water supply, another investment to secure the stable water supply throughout the year enabled far more enhancement of productivity in this sector, rice in particular, to meet the increasing demand for basic foods. A double or even triple cropping of rice was made possible in the tropical and semi-tropical countries, and the irrigation systems combined with a larger input of fertilizer are said to be essential to introduce the high yield varieties. This kind of investment to enhance agricultural production is highly required particularly in the early phase of economic developments (Figure 3).

#### **iii) Short term fluctuation in the precipitation**

As mentioned above the most serious risk takes place in the period of abnormal dry spells in the rainy season. More investments to store water will be required in order to relieve these risks.

The collective use of irrigation water and the longer history of property rights establishment for water accompanied with the aforementioned investments are other outstanding features in Asian countries. The farm size is small in paddy field rice production, the unit of irrigation systems compared to the farm size is much larger, the gravity systems are commonly applied to introduce water from the source to many production sites, and in conclusion collective actions are inevitable. In the context of economic theory, the technical reason that there is a large extent of economy of scale in the paddy field irrigation makes the collective action economically efficient. Relating customs, community rules and social norms specific to each region have also been established in static communities.

Figure 2. Implicit water market and the rent of scarce water: Short run



Let demand curves for water in agricultural and non-agricultural sectors be  $D_A$  and  $D_N$ . For simplicity, we assume the marginal cost of water supply is determined by the O&M cost at the same rate in both sectors.

(A) Under the condition of abundant water, the equilibrium is attained at  $E_A$  and  $E_N$  independently at  $p^*$  that is equal to the O&M cost. No scarcity rent will be generated.

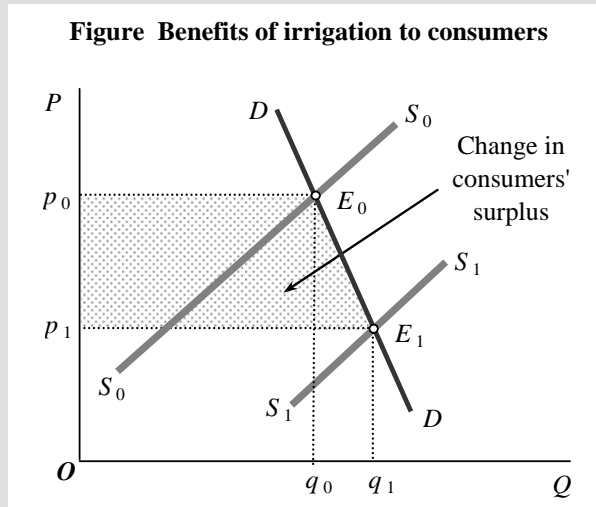
(B) In the period of water shortage,

(B-i) the economically efficient allocation is attained at  $E$  where the water price that consists of the O&M cost and scarcity rent equalizes the marginal benefits in both sectors.

(B-ii) if the water right is established, e.g. at  $q_A^R$  for the agricultural sector, proper reallocation of water from the agricultural to the non-agricultural sector will enhance economic efficiency.

Proper investments in water storage can change the condition in (B) into that in (A). The scarcity rent will be embedded into the capital investments.

**Figure 3. Benefits of irrigation to consumers**



Assuming an irrigation project increases the agricultural productivity, the supply function of the food product shifts from  $S_0$  to  $S_1$ , the equilibrium moves from  $E_0$  to  $E_1$ , and the market price will go down from  $p_0$  to  $p_1$ . Because the food demand is inelastic to price changes, the change in benefit of the consumers given as the area of  $P_1E_1E_0P_0$  will dominate the change in producers' surplus (not indicated in the figure).

In addition, the agriculture based on paddy fields would minimize the contradiction to the natural habitat, and even enhance it through multifunctionality (see Yamaoka, 2006a). The public nature of water is further strengthened by the fact that water in open channels and even stored in paddy fields is a kind of open-accessible resource. These facts show some of the public nature of water in society.

Taking into consideration the above features, society should make a successful consensus to deal with the emerging demand not only due to the agricultural development but also from municipal and industrial sectors associated with the economic growth and the population increase particularly in cities. Capital investment will be the prompt instrument in reducing the scarcity of water even in the period of dry spells and will contribute in the providing of technologically efficient water but some mechanisms will be essential in achieving economically efficient allocations of water.

In order to achieve the latter purpose, economic instruments such as the establishment of water markets or the proper pricing to equalize the marginal benefit of water use everywhere, are highly recommended in many literatures. Many prerequisites, however, should also be recognized at the same time, and social and political considerations tend to prevent such directions. In our view, the classical argument above reviewed for example in Zilberman & Lipper (1999) would not conclude in a single solution, depending on the social and historical contexts in the specific country/region.

### **3. The Japanese case: Required knowledge and information for better management**

#### **3.1.1 Basic framework of the Japanese water management**

The Japanese water management would be a typical example for many other countries. Property rights for water were established based on preoccupation and riparian use throughout a long history. The water rights are particularly meaningful in periods of drought. In addition, competition has emerged in the industrial and municipal sectors against the agricultural sector due to the industrialization and expansion of urban areas since the Meiji Era (since 1868).

Because the precipitation in Japan is enough to meet the emerging demand *on average*, it has been fulfilled to a large extent by newly invested infrastructures to reserve water during water surplus periods. Water rights have been newly established not to contradict the formerly established ones in the agricultural sector. The fact that water use is heavily dependent on the surface water compared to the ground water and that paddy field agriculture is common in the entire country generates strong economies of scale. Most investments to secure the water supply have been conducted as public enterprises, and have created water rights to entitle new users who have contributed to the projects. Legislation has been drafted based on the recognition of the public nature of water and the trading of water rights is banned.

Irrigation water in the agricultural sector is managed by each irrigation district, called *Land improvement district* (LID), based on its water rights. The LID is an autonomous organization administered by farmers. The membership is connected to the land irrigated and collective actions dominate based on the customs and norms formulated in the long history. The LID is responsible for the collection of fees from farmers to cover all of the O&M costs and the loan payments for the capital investment a large part of which is subsidized by the government. The farmers are usually charged for irrigation water proportionate to the land area, because the volumetric rate of tariff is not realistic in most cases of paddy field irrigation that use gravity systems (Kobayashi, 2006).

The local governments, i.e., municipalities (cities, towns and villages), manage the water supply for industrial and residential uses (i.e. tap water) based on their water rights. The enterprise, combined with sewage water treatments, is also administered autonomously, and the consumers pay for the water supplied and for the sewage water treatments at the same time. The 'tiered block rate' coupled with a fixed rate is normally applied. The prices of tap water and sewage treatments seem to vary widely among municipalities.

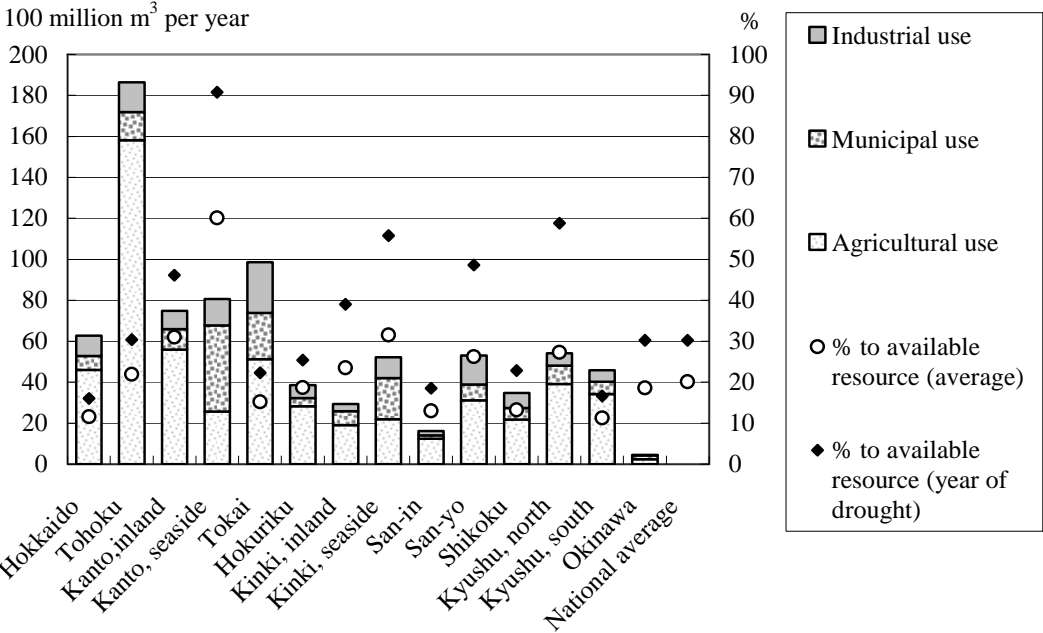
#### **3.1.2 Statistics of Japanese water use**

In the Japanese case, the maximum availability of water for human uses based on the average annual precipitation of 1,600 mm/yr and the estimated evapo-transpiration is reported at about 410 billion cubic meters (m<sup>3</sup>), while the human use counts a 20% at 83.4 billion m<sup>3</sup>, of which the agricultural, industrial and municipal sectors share 66% (54.9 billion m<sup>3</sup>), 15% (12.6 billion m<sup>3</sup>) and 19% (15.9 billion m<sup>3</sup>), respectively. The share of agriculture in the GDP is about only 0.9% in 2007. The Japanese GDP in 2008 is 507 trillion yen (USD 4.9 trillion) according to the UN database.

The above statistics although, officially distributed, are misleading because the figures

indicate the water withdrawn at the source. Irrigation water in the paddy field that is well facilitated with drainage runs back to the lower river by, seemingly, 50-70%. The percentages are varying depending on districts and crucial when water or water rights are to be reallocated from the agricultural sector as discussed in the following parts. The water use in the Japanese industrial sector is estimated at 52.1 billion m<sup>3</sup> including recycled uses, compared to the 12.6 billion m<sup>3</sup> of withdrawals from the source in 2006.

**Figure 4. Japanese water use by sector in 2006**



Source: *Nihon no mizu sigen 2009 (Water resource in Japan)*, Ministry of Land, Infrastructure, Transport and Tourism.

- Note (1) Average available water resource is defined as the total precipitation minus the disappearance due to evapo-transpiration in the period from 1976 to 2005.
- (2) The drought assumes the third lowest precipitation during the period of 1976-2005.
- (3) A large part of water consumed in the Kanto Seaside is caught in the Kanto Inland.

**3.2 Reallocation of water among sectors**

Looking at the recent trend in Japan, (1) Capital investments of dams and reservoirs have become more and more limited in spite of some basins often still facing events of water shortage, (2) rice production has been decreasing due to the lack of demand and the population growth and industrial activities seem to have stagnated, so the rapid growth of water demand is not expected in the future, (3) annual fluctuations of precipitation might have been more significant. Two issues would be prominent for a better water supply management, i.e. (1) temporal water transfers during abnormal dry spells and (2) permanent transfers of water rights, both among sectors. We focus on those from the agricultural sector to the residential sector.

### 3.2.1 Reallocation of water in the period of abnormal dry spells

Based on the Japanese systems of water management, water users consult with one another and, in the spirit of mutual compromise, do not take the market approach but take voluntary steps to save water. In abnormally dry spells, every water user wants additional supplies of water. The cost of water therefore rises considerably. The costs are imposed on end-users: in the case of agricultural water users, in the form of an increase in labor input on managing water distribution; in the case of municipal water users, in the form of reducing convenience. If the dry spell grows even worse, the costs rise further because of the decline in crop yields, or the suspension of water supply and rusty tap water.

Taking into consideration these various costs, the most persuasive approach, and hence the one normally adopted, is an equitable saving that calls for all parties to cut back their regular water consumption by the same percentage. Nonetheless, it does happen that certain users may voluntarily curtail their water use even further. The amount of water, which is equivalent to the difference in the percentage by which relevant users cut back on their water consumption, i.e. the difference in the water-saving ratio, could be defined as a water transfer on a temporary basis.

A typical example of this is that of the Aichi-yosui waterworks system which is the first large scale integrated water resource development project in Japan (Yamaoka et al., 2006). The Aichi-yosui has provided water for agricultural, industrial and residential uses in the Aichi prefecture located in central Japan since 1961. This system has Makio reservoir as a main reservoir, three reserve ponds, 112.1 km of main canal and 1,012 km of branch canals as the main facilities. They provide 21 m<sup>3</sup>/s for agriculture, 6.5 m<sup>3</sup>/s for residential use and 9.2 m<sup>3</sup>/s for industrial use after the completion of a new project.

The annual volume of water discharged from the Makio reservoir for water users increased dramatically from 143 million m<sup>3</sup> in 1963 to 475 million m<sup>3</sup> in 1999. The Makio reservoir operation has become more difficult and the discharged volume of water has repeatedly been restricted according to the increased demand for water. During the 30 years from 1973 to 2002; a) a water saving ratio was regulated to reduce the amount of water to be discharged from the reservoir in 20 years, b) the water saving ratio for agriculture exceeded 20% in 16 years, and c) agriculture granted water to the municipal sector during abnormally dry spells by regulating a relatively higher water saving ratio over 15 years. In conclusion, the water transfer happens very often in the Aichi-yosui territory

Yamaoka (2006b) suggests that the repeated experiences of reconciliation among farming families and between villages in history have strengthened their spirit of reciprocity, mutual confidence and surveillance to check free-riders, local discipline and norms for their collective actions. These networks among farmers underpinned by trust and spirit of reciprocity would be termed "social capital", which is conceptualized by Putnam (2000)

Similar cases happened in the period of the nationwide abnormal dry spell in 1994 and 2005. In the summer of 1994 28 river basins in the country suffered from serious droughts. The water saving ratio for agricultural use exceeds that for residential use in cases of 23 river basins. That is regarded as the actual water transfer in the temporary basis between the sectors.

Rice farmers can reduce labor costs for farming by using the ample and cheap irrigation water because of the existence of wide-ranging substitutability of water for farm labor as factors of production. This means, on the contrary, during abnormal dry spells, farmers can to a large extent, reduce the amount of water use in exchange of additional labor inputs. Farmers need a well organized collective action among them for equitably distributing scarce water as well as for investing in additional labor because existence of free-riders may undermine their cooperation.

### **3.2.2 Permanent reallocation of water rights**

The permanent reallocation of water among sectors is also consulted in the periodical water rights review by the government (Kobayashi 2006). Some examples are kinds of transfer in water rights negotiated among users, i.e. some specific LIDs and municipalities. In these cases a municipal sector requiring for an increase in water rights invests in capitals to create new resources of available water. The investments are not in the form of large scale public enterprise such as dams and reservoirs, but in the form of a renewal investment in agricultural irrigation facilities which saves water and creates new water rights for the municipal sector. In the agricultural sector, a decrease in the leakage of water and an efficient water distribution in the canals and fields will be achieved by these investments, and the required water withdrawn from the source could be also decreased.

The amount of water rights newly created is evaluated officially in the review by the government. The agricultural sector will release a part of its water rights, but the renewal investment above will improve the efficiency in agricultural production (Takada et al. 2002). The agricultural sector has some incentives in this *trade*. The municipal sector can find a way to have new water rights much cheaper than those by large scale capital investments, even if it pays all for the investments. The municipal sector, however, has a reason to require the agricultural sector to pay some for the above investments, because the latter sector will also benefit, although to a limited extent, as mentioned above. Who pay the cost for the investment is decided by negotiations among sectors. Takeda (2004, 2005a, 2005b) analyzed the case in Saitama prefecture where the number of negotiations between municipal and agricultural sectors were conducted during the period from 1968 to 2006.

### **3.3 Required knowledge and information in the negotiation and water rights review**

We could suggest two questions which are raised when negotiations of water and water rights reallocation among sectors and the review of water rights are conducted. Firstly, the characteristics and price responsiveness in residential water demand are not necessarily well acknowledged by the stakeholders. That is particularly important in the case of temporal water transfer in the period of drought. The agricultural sector tends to bear higher saving ratios and a concluded increase in cost as explained above, but the municipal authorities never change the price to reduce the residential water consumption which might be required taking into consideration the temporal increase in the scarcity of water. After the negotiation among sectors, the residential water consumption is saved by means of command and control by the municipal authorities.

Secondly, how much water and water rights would have become available by the decrease in withdrawals from the agricultural sector depend not only on the corresponding amount but also on the amount of water running back to the river flows after irrigating the paddy fields as indicated previously.

### **3.3.1 Residential water demand**

When the water use should be limited in the abnormal dry spells, the municipalities face difficulty in managing the residential use, albeit the saving ratios suffered in this sector are the lowest. The agricultural sector could reach the target under the collective actions as mentioned above. The industrial sector involves small number of users and recycled uses are common in the sector.

A temporal increase in the tap water tariff, once realized, might be the instrument that is economically more efficient than command and controls. The knowledge and information on the tap water demand is essential in this consideration. The following outlines the key statistics to be considered further in the future work. First we look at the general feature of household consumption.

While the average price is widely varying among municipalities, the structures of tariff are general ones which apply tiered increasing block rates combined with a fixed rate. Table 1 and Figure 5 show the example in Tokyo. Figure 6 indicates that high income families pay more to the tap water (per person). The outstanding feature, however, is that low income families pay more to the tap water, also. The average age and family size of the first and the second income quintiles are 64 and 61 years old, and 1.16 and 1.62 persons, respectively. The decreases in the expenditures up to the income quintile VIII reflect the larger numbers of family members.

The above examples imply that the expenditure to water is a heavier burden for the families of low income, single and old persons. The overall increase in the tap water tariff is not compatible with the equity concerns, and difficult to be acceptable in the society. In addition, low income larger families facing the increasing block rates tend to bear heavier burdens when the price is going up.

The raising tap water prices should be carefully managed taking into consideration the evidence like above and the effectiveness to reduce the actual tap water demand. The second important point is that on price responsiveness of tap water demand. If the tap water demand does not respond to the price changes at all, the command and control must be the only instrument to save municipal water.

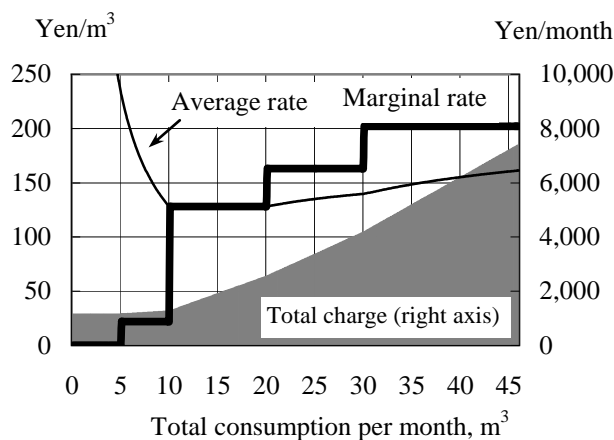
Many literatures suggest that the demand of tap water is inelastic to the price changes (Takada et al. 2004). We also tried a very simple estimation using the average price of water and estimated the corresponding elasticity at minus 0.12 (statistically insignificant, although 4). However, the statistical estimation in this case is quite difficult because of the complicated structure of tariffs. The consumer will respond to the price itself and the price structure at the same time (Olmstead et al. 2007). Some combination of tariff structure and price changes might be effective to control tap water demand not to contradict with the social interests such as equity concerns. Evidences are

limited to be clarified.

**Table 1. Tiered tariff for tap water in Tokyo**  
per month

Fixed rate	1,170 yen
Tiered rate yen/m <sup>3</sup>	
-5m <sup>3</sup>	0
-10m <sup>3</sup>	22
-20m <sup>3</sup>	128
-30m <sup>3</sup>	163
-50m <sup>3</sup>	202
-100m <sup>3</sup>	213
-200m <sup>3</sup>	298
-1000m <sup>3</sup>	372
1,000m <sup>3</sup> -	404

**Figure 5. Tap water price and charge in Tokyo**

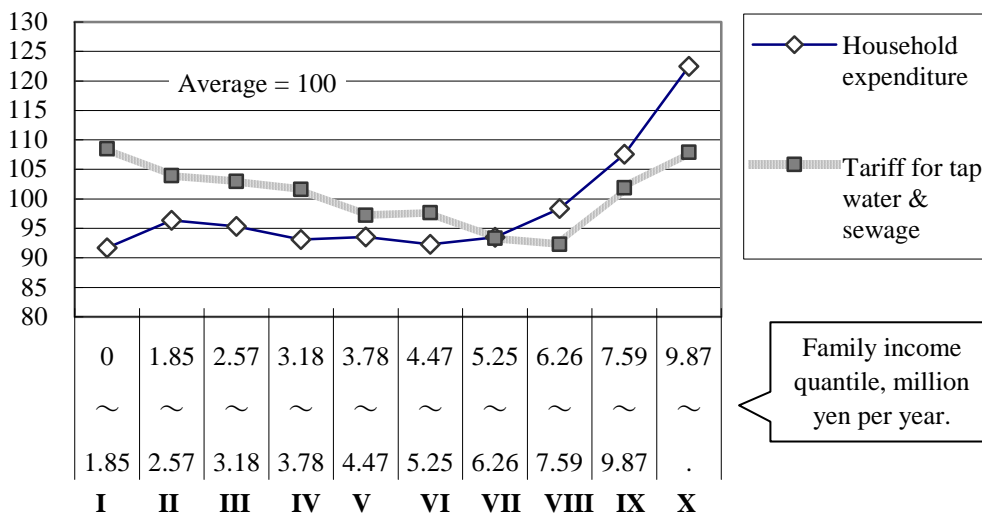


Source: Tokyo Metropolitan Office, <http://www.waterworks.metro.tokyo.jp>.

Note: Assuming a normal residence consuming 24m<sup>3</sup> pays 3,372 yen per month including 5% tax.

The first author (four family members) paid 7,429 yen for two months (February/March, 2010), while the sewage treatment was charged at 5,712 yen.

**Figure 6. Household expenditure for water service per person**



Source: *Family Income and Expenditure Survey*, the Statistics Bureau and the Director General for Policy Planning, Ministry of Internal Affairs and Communications.

**Table 2. Estimation of tap water demand**

Explanatory variable	Coefficient	t-values
Household expenditure	0.778	5.27
Average price	-0.116	-0.72
Family size	-1.72	-4.98

Note: R squared adjusted by the degree of freedom is 0.985.

Source: *Household income and expenditure survey*.

### 3.3.2 Running back ratio in the agricultural water use

Here we define the running back ratio as the amount of water running back to the river flows after irrigating the paddy fields to the original amount withdrawn from the source. It reflects the water demand that is gauged in terms of *Gensuishin* in irrigation agriculture and is evaluated as a unique number of the combination of fields and canals. It is also determined by several parameters, such as characteristics of soils, weather conditions and so forth, and different by time and location. The *Gensuishin* means a decreasing rate of irrigation water in the closed field. The running back ratio seemingly reaches 50-70% and will decline when a smaller amount of water is withdrawn.

The percentage, not necessarily clear in the reality, actually plays a critical role when the reallocation of water rights from agricultural to the municipal sector is finally approved by the government. In the case whereby the agricultural sector agrees with the release of an amount of water rights corresponding to a specific period, the municipal sector could not take that amount because it involves the water running back to the river flows even if the agricultural sector uses the same amount of water as before. If the running back ratio reaches a 70%, the reallocated water rights to the municipal sector are 30% of those released by the agricultural sector. Serious controversies actually occurred among municipalities and authorities of the central government. The cases in Saitama prefecture are considered in Takeda (2005).

Although the running back ratio does not seem to be seriously considered in cases of negotiation on the temporal reallocation of water, the accurate information would help more efficient and persuasive decision making, and in addition would give essential background information.

### 3.4 Future prospects of the climate change

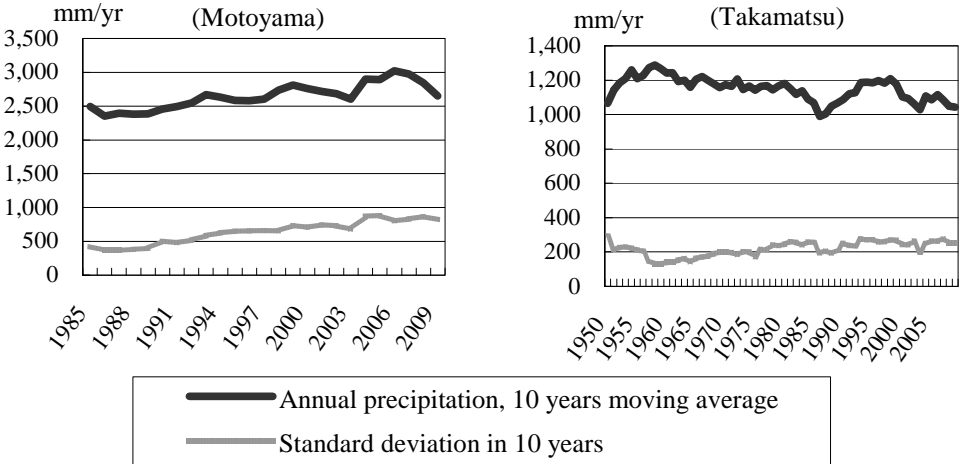
Though this issue is out of scope of the research fields of the authors, some statistics might simply suggest the increasing possibility of temporal water shortage. Figure 7 indicates the annual precipitation (ten years moving average) and changes in its fluctuation (standard deviation in ten years) in Motoyama (located in the upstream of the Sakai river basin) and Takamatsu (located in the lower part of the Yoshino river basin). The data in, for example 2008, is calculated by the data from 1999 to 2008.

During the period from 1964 to 2008 the Sakai and the Yoshino river basins faced serious droughts in 1995, 1997 and 1998, and 1973, 1994, 1998, 2005, 2007 and 2008, respectively according to the government report. The events look happens more often in the recent years and

these facts are consistent to the Figure 7.

Similar relationships were not found in some of the other basins recently suffering from serious droughts. The examples of the two above cases may not adequate as scientific evidence, so further information from the meteorological field should be collected and distributed among policy makers.

**Figure 7. Changes in precipitation and annual fluctuations in the selected sites**



Source: Japan Meteorological Agency.

**4. Conclusion**

Other than capital investments and renewals of old facilities for a more secured water supply to cope with the annual fluctuations of available water resources, reallocation of water and water rights among agricultural, industrial and municipal sectors can play an important role in the Japanese case. We indicated two important aspects for better management: (1) knowledge of the structure and price responsiveness of residential water demand is required for the municipal sector to control the water demand in a socially acceptable manner, and (2) how much water becomes available to other sectors when the agricultural sector reduces irrigation water use should be the basic information for the reallocation of water and water rights among sectors. The second aspect is particularly important for the countries located in the monsoon districts, the agriculture of which is dominated by irrigation agriculture of paddy field.

More detailed information on the future prospect of precipitation pattern under the climate change is also required to secure the stable water supply all over the country.

**Note**

- 1) The other countries/regions of higher precipitation are located in the Central America, the northern part of South America, Madagascar and the western part of the equatorial Africa. Here we do not consider the country size, but the average precipitation is one of the main determinants of water resource availability (Anand, 2007, pp.25-32).
- 2) The Pearson’s correlation coefficient between the mean annual precipitation and the

coefficient of variation (standard deviation of monthly precipitation divided by the annual mean precipitation) was calculated at 0.59, using 79 country samples from the *AQUASTAT* (<http://www.fao.org>) and the WMO (<http://worldweather.wmo.int/>).

3) The difference between surface water and ground water (exhaustive or depletable resource) in the economic theory was discussed in Kobayashi (2006).

4) A log linear estimation was applied on the following function using data from the *Household Income and Expenditure Survey*.

Water demand per person = f (Household expenditure, Average price of tap water, family size)

## **Bibliography**

Adler, R.F., G. Huffman, A. Chang, R. Ferrapo, P. Xie, J. Janowiak, B. Rudolf, U. Schneider, S. Curtis, D. Bolvin, A. Gruber, J. Susskind, P. Arki & E. Nelkin “The Version-2 Global Precipitation Climatology Project (GPCP) Monthly Precipitation Analysis (1979-Present)”, *Journal of Hydrometeorology*, pp.1147-1167, December, 2003.

Anand, P.B., *Scarcity, Entitlements and the Economics of Water in Developing Countries*, Edward Elger, USA, New Horizons in Environmental Economics, 2007.

Kobayashi, H. “Japanese Water Management System from an Economic Perspective: The Agricultural Sector”, in OECD (2006), pp.121-136.

OECD *Water and Agriculture: Sustainability, Markets and Policies*, 2006.

Olmstead, S.M., W.M. Hanemann & R.N. Stavins, “Water demand under alternative price structures”, *Journal of Environmental Economics and Management*, 54, 2007, pp.181-198.

Putnam, R. *Bowling Alone: The Collapse and Revival of American Community*, Simon Scuster, New York, 2000.

Takada, S. Tsuboi, N. & Shigeno, S. “Shadow Price and Reallocation of Water Resources in Japan: Transfer from Agricultural Water to Residential Water“, *Rural Economics and Sociology*, The University of Tsukuba, 2002, pp.1-29 (in Japanese).

Takeda, M. “Mizu shigen no youto-kan saihaibun to hiyou hutan (Inter-sectoral reallocation of water resources and cost bearing)”, *Suiri Kagaku (Water Science)*, No.282 pp.57-84 & No.283 pp.90-120, 2005 (in Japanese).

Takeda, M. “An Economic Analysis of Inter-sectoral Reallocation of Water Resources”, *Journal of Rural Economics: Special Issue 2004*, pp.308-315 (in Japanese).

Yamaoka, K. (2006a) “Paddy Field Characteristics in Water Use: Experience in Asia”, in OECD (2006) pp.287-315.

Yamaoka, K., Y. Ichida, K. Asano, T. Tomosho, N. Horikawa & R. Yonghuai “Social Capital and Economic Rationality in Transferring Agricultural Water to Domestic Use During Abnormal Dry Spell”, ICID 3<sup>rd</sup> Arc held in Malaysia, 2006b.

Zilberman, D. & L. Lipper “The economics of water use”, *Handbook of Environmental and Resource Economics*, Joroen C.J.M van den Bergh ed. Edward Elger, USA, 1999.