A PRELIMINARY STUDY OF
THE DROUGHT MITIGATION PRACTICES OF AGRICULTURE SECTOR
IN JAPAN AND LOOKING FOR POSSIBILITIES
TO APPLY BEST PRACTICES TO SRI LANKA

RESEARCH REPORT PRESENTED BY

W.M.S.B.WANNINAYAKE
Assistant Director (For Kurunegala District)
Disaster Management Centre, Ministry of Disaster Management, Sri Lanka

To the Asian Disaster Reduction Centre
Kobe, Japan

in partial fulfillment of the requirement
for the Visiting Researcher Program (2011 A)

29 August 2011

Disclaimer

Acknowledgement

My deepest gratitude is expressed to Mr. Shigeru ITOH, the Chairman of the Asian Disaster Reduction Center, Mr. Atsushi KORESAWA, the Executive Director, and his staff, Asian Disaster Reduction Center, Kobe, Japan for giving me the opportunity to work as a Visiting Researcher at ADRC.

Profound gratitude and appreciations also expressed to the Hon. Mahinda Amaraweera, the Minister for Disaster Management in Sri Lanka, Mrs. S.M.Mohamed, the Secretary to the Ministry of Disaster Management, Major Gen. Gamini Hettiarachchi (Retd), the Director General to the Disaster Management Centre of Sri Lanka and Mr. U.W.L.Chandradasa, Director to the Disaster Management Centre of Sri Lanka for giving me this opportunity to attend to the Visiting Researcher Programme of ADRC, Kobe, Japan.

My very sincere thanks are also expressed to Ms. Miki KODAMA, the Senior Researcher, ADRC, Kobe, Japan for her valuable guidance, suggestions, encouragement and support throughout the period of my study.

My special thanks go to Mr. Tetsuo IBARAKI, the Senior Researcher, ADRC, Kobe, Japan for giving me guidance and support as my Mentor, throughout the study.

A special word of thanks goes to Mr. Takahiro ONO, the Senior Researcher, Miss Yumi SHIOMI, Mr. Makoto IKEDA, the Researchers, for their support to complete my study.

I must also mention here thanks to the other Researches, all the staff members of the Administration Section and Mr. Kawahara, the Language Teacher and all the others whose names are not mentioned but helped me to fulfill my target, for their valuable and helpful support for me to complete my study.

Finally I express my sincere thanks to my dear colleagues of Visiting Researchers, Mr. Emin NAZAROV from Azerbaijan, Mrs. Anna-lisa ORALLO from the Philippines and Miss Surina Binti OTHMAN from Malaysia, for their valuable support for me to complete the study.

Table of Contents

A preliminary study of the drought mitigation practices of agriculture sector in Japan and looking for possibilities to apply best practices to Sri Lanka.

CHAPTER 01 – INTRODUCTION

1.1 Background of the Research

Drought can be simply defined as a situation where human demand for water exceeds the available supply. Drought implies a lack of moisture for an extended period of time which in turns causes a deficit of moisture in the soil. Many problems can arise due to droughts, including crop damage and water supply shortage.

How severe a drought is depends mostly on the degree of the deficiency, the time period, and the size of the area affected. The timing is also a significant factor with the duration of droughts. Droughts result from a combination of meteorological, physical and human factors. Their primary cause is a deficiency in rainfall and the timing, distribution and intensity of this deficiency in relation to existing storage, demand and water use. Temperature and evapotranspiration may act in combination with insufficient rainfall to magnify the severity and duration of droughts. Moreover, due to changes in land use, water demand and climate the droughts in future may become more frequent and more severe.

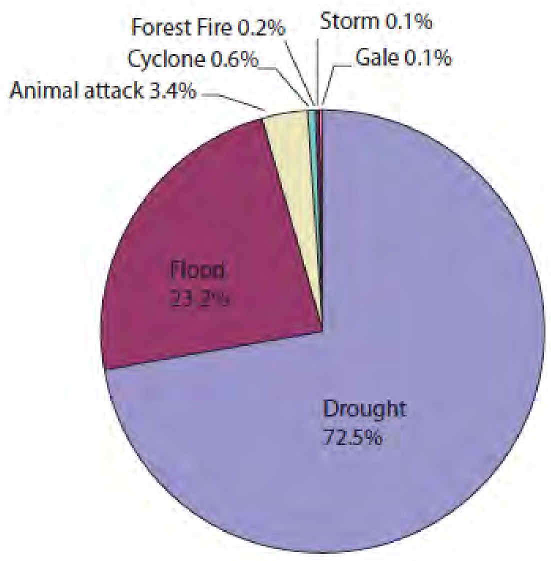


Figure 01: Impact by disasters on crops and paddy from 1974 to 2007 in Sri Lanka

There are four major classifications of droughts.

1. Meteorological drought: Usually expressions of precipitation's departure from normal over some period of time. Reflects one of the primary causes of a drought.
2. Hydrological drought: Usually expressions of deficiencies in surface and subsurface water supplies. Reflects effects and impacts of droughts.

3. Agricultural drought: Usually expressed in terms of needed soil moisture of a particular crop at a particular time.
4. Socio-economic drought: Definitions associating droughts with supply of and demand for an economic good.

Over the past few decades, drought losses worldwide have grown exponentially. According to the previous experiences of natural disasters, droughts have made the biggest damage to the agriculture of Sri Lanka than any other disaster such as floods, landslides or tsunami. As the figure 1 shows the impact on crops and paddy from 1974 to 2007, it is clear that droughts account for the largest proportion of crop losses.

1.2 Objective of the Research

To study the Japanese drought mitigation practices and by means, to identify the best practices which can be applied in Sri Lanka.

1.3 Significance of the Research

As a country mainly based on agriculture the Sri Lanka should take the possible maximum production in agriculture and should try to minimize the losses by droughts to keep the development targets, especially in economy. Therefore it needs to find solutions how to mitigate these droughts' effects in agriculture of the country. In the sense this research is done to study the Japanese lessons and strategies for drought mitigation.

CHAPTER 02 – METHODOLOGY

2.1 Data Collection

Data collection was mainly done from websites which have been mentioned in references. Some information was gained by field visits and lectures at some sites which drought mitigation practices are going on.

2.2 Data Analysis

Analyzed data in previous studies were mostly used for the research. Descriptive method has to be applied, rather than any statistical or mathematical analyzing tools due to very concentrated period of time to complete the research.

2.3 Study Area

Agricultural areas in Japan and Sri Lanka where droughts are occurred in time to time were considered as the study area.

2.4 Limitation of the Study

I had to complete the research within a limited period of time and therefore only very few research techniques were able to apply to the study. The Study would be introduced as a preliminary study.

CHAPTER 03 – DROUGHTS IN JAPAN

3.1 Fluctuation of Precipitation in Japan due to Climate Change

As the long-term trend of temperature change in Japan, the average annual surface air temperature has increased by approximately 1^{o}C over the past 100 years. Concerning precipitation, years of low rainfall have become frequent since around 1970, and the amount of precipitation was much below average in 1973, 1978, 1984, 1994, and 1996, when water shortages caused damage. Recently an increasing trend of fluctuation between extremely low rainfall and extremely high rainfall has been observed. In addition to the above-mentioned decrease in precipitation and frequent occurrence of extremely low rainfall years, due to climate changes accompanying global warming, trends of decreasing snowfall and increasingly earlier thaw have been recognized.

3.2 Declines in Water Supply Stability

When constructing dams in Japan, they are designed so as to secure the necessary water supply even in a year of relatively low rainfall (base year for water supply). When annual precipitation is much lower than in the base year, the river flow also decreases more than in the base year. On the other hand, since the storage capacity of water remains fixed, it would be impossible to secure stable intake of water throughout the year, even with replenishment from dams. For 60 % of the dams now in operation, the base year is selected from between 1956 and 1975. Assuming that 1960 is the base year for water supply, in 9 out of about 40 subsequent years, annual precipitation was lower than that in the base year. It means that water short ages occurred frequently. It is thus considered to be a problem that stable water supply has been impaired in many places in recent years.

3.3 Examples of Decline in Water Supply Stability

Water resources development facilities in the Kiso River System include Tokuyama Dam (under construction), Nagara River Estuary Barrage, Miso River Dam, Aki River Dam, Iwaya Dam and Makio Dam. At present, when all of these facilities are in operation, 88 m^3 of water per second is planned to be supplied. However, the calculation using flow rate in the year of the second lowest rainfall during the 20-year period from 1979 to 1998 showed that only about 59% of the planned amount (equivalent to 1/10 water shortage) can be stably supplied. Further, in the calculation using the flow amount in 1994 when serious water shortage occurred, the water amount suppliable reduces to about 30% of the planned amount

3.4 Occurrence of Water Shortage

Previously, Japan repeatedly experienced major water shortages; for example, 1939 in Lake Biwa, 1964 in the year of Tokyo Olympics, 1967 in Nagasaki, 1973 in Takamatsu, 1978 in Fukuoka, and so on. Though occurrence of water shortages has become rare in recent years the shortage in 1994 covered almost all Japan, when approximately 16 million people were affected at least once by suspended or reduced water supply, and agriculture suffered production losses of 140 billion yen.

The Figure 02 shows the previous occurrence of water shortages in Japan. According to the Figure 02, water shortages have been reported in ten Prefectures of five regions from 1991 to 2010. The details of the affected areas are as follows.

<Shikoku region>
A1: Kagawa Prefecture
A2: Chuyo area, Ehime Prefecture
B1: Central area, Kochi Prefecture

<Kyushu region>
B2: Central area, Fukuoka Prefecture
B3: Kitakyushu area, Fukuoka Prefecture
B4: Fukuoka area, Fukuoka Prefecture
B5: North area, Nagasaki Prefecture

<Kinki region>
B6: North area, Wakayama Prefecture
B7: North area, Nara Prefecture

<Tokai region>
B8: West area, Aichi Prefecture
B9: East area, Aichi Prefecture

<Kanto Koshin region>
B10: Gunma Prefecture
B11: Saitama Prefecture

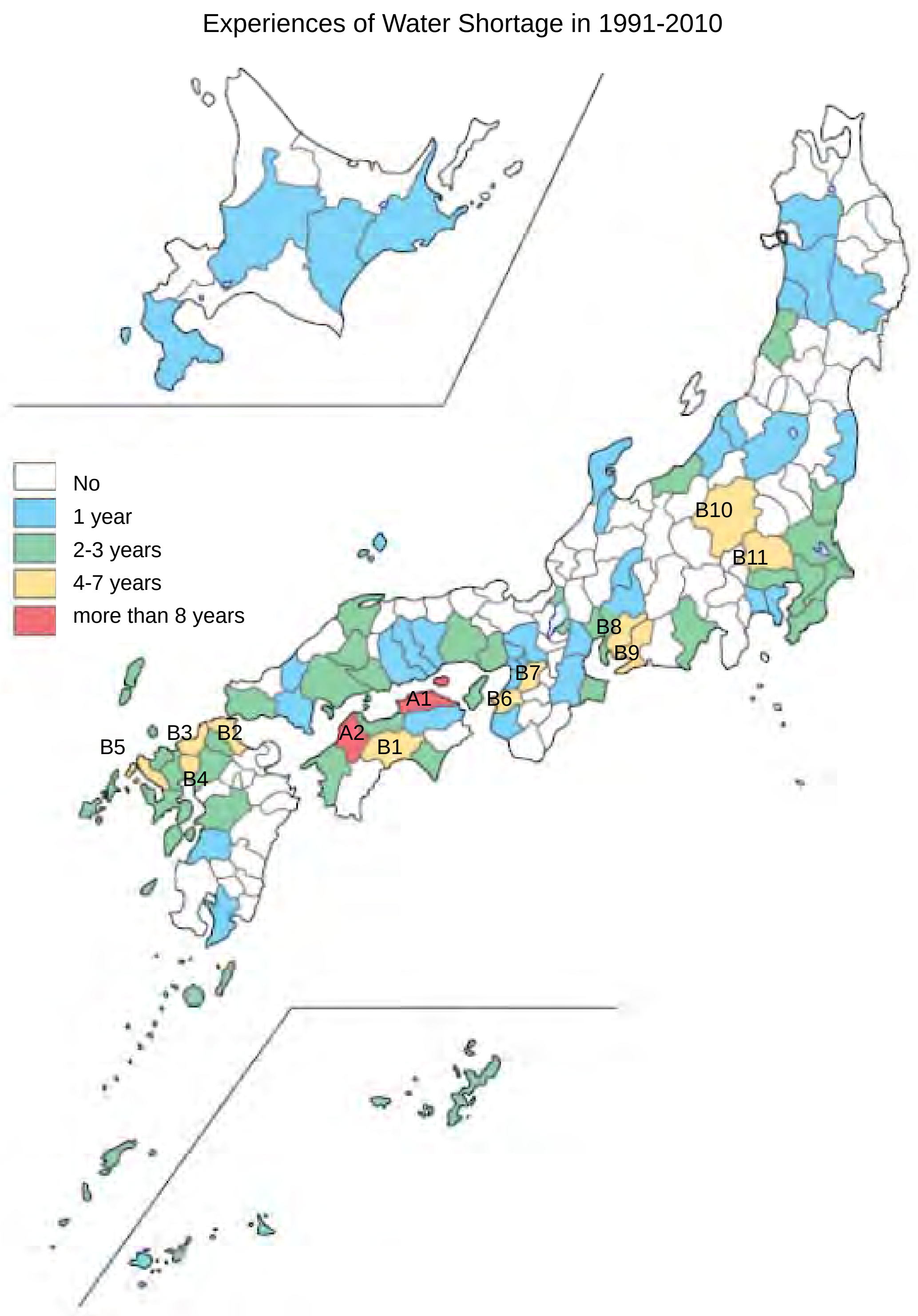


Figure 02: The numbers of yearly interruptions or restrictions of water supply systems in 20 years (1991-2010)

Though Japan receives abundant precipitation due to regular monsoons, water shortages are frequent, due to the spatial and temporal variation of rainfall, marked topographic differences, small river catchments and sudden drops in altitude causing short and swift rivers. This situation is further aggravated by severe droughts. The amount of available water resources per capita is 3,300 m^3/year. Total annual water use is approximately 85.2 billion m^3, 88 percent of which is obtained from rivers. The agriculture sector makes up more than 65 percent of annual water abstraction, followed by domestic and industrial uses (20 and 15 percent respectively).

Based on the 1961 Water Resources Development Promotion Law, comprehensive water resources development (including infrastructure like water supply reservoirs) and efficient use of water resources have been advanced in order to ensure a stable supply of water resources over a wide area to respond to the rapid development of industry and increase in urban population. Water for flooded rice paddy fields and fish culture comprises most of Japan's agricultural water use. For the last two decades, agricultural surface area has been decreasing. However, due to increasing requirements for higher crop productivity and measures on water quality, the amount of water utilized for irrigation has not changed significantly. Due to its limited amount of cultivatable surface area, Japan imports many products, especially grains, crops and meat.

Following the enactment of the "River Law" in 1964, which is the Legal Framework for River and Water Management in Japan, use of agricultural water, which accounts for two-thirds of all water intakes, has remained more or less stable despite the decreasing area of paddy fields. Industrial water use has also remained unchanged thus far because of the changes of industrial structure and the improvement in the recycling rate. Domestic water use, in contrast, is still growing owing to changes in lifestyle. Precipitation has been on the decrease in recent years, causing frequent droughts in the Tokyo metropolitan area, the Chubu region and western Japan. The drought of 1994, for example, had a far-reaching and serious impact, affecting almost the entire country. So the water resources development today is planned on the basis of a design drought having a return period of 10 years. By the standards of the international community, this factor of safety is low.

Water restriction was carried out due to the drought situation in 20 of 109 river systems in Japan in 2005. The Figure 03 shows the river systems and rivers affected by droughts in years 2005.

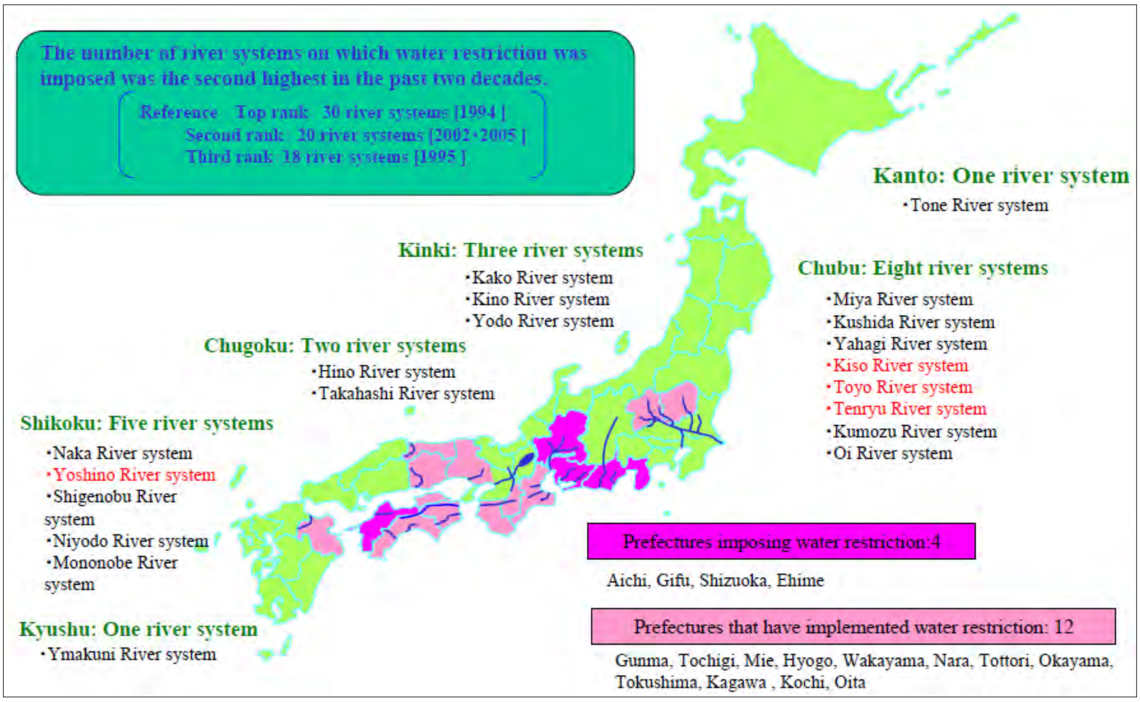
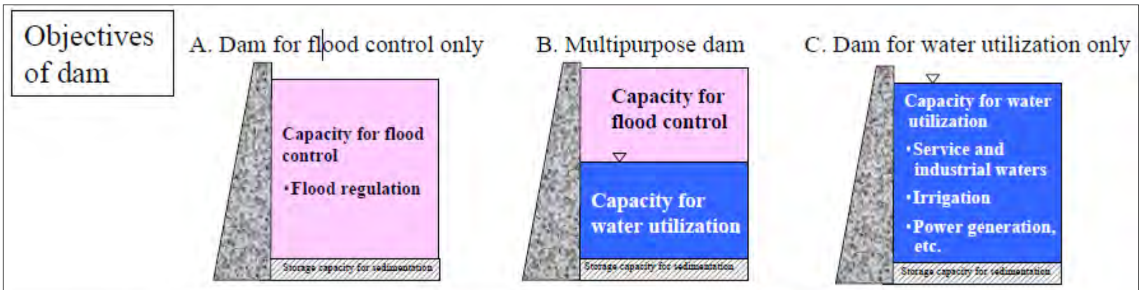


Figure 03: The river systems and rivers affected by droughts in 2005

3.5 Water Resource Management and Dams in Japan



Number of dams

Class	Administrator	Category	No. of dams
Under control of the Ministry of Land, Infrastructure, and Transport	Under direct control of the Ministry	A,B	81
	Dam Division, Japan Water Agency	B	20
	Prefecture	A,B	338
	Subtotal		439
Under control of the Ministry of Agriculture, Forestry, and Fisheries	Under control of the Ministry	C	152
	Canal Division, Japan Water Agency	C	17
	Prefecture	C	1567
	Subtotal		1736
Others	Electric power suppliers	C	399
	Service and industrial waters (Enterprise Bureau, local authorities)	C	129
	Total		2703

As of December 2005
Surveyed by
the Water Management office, the Ministry of Land, Infrastructure, and Transport

Figure 04: Objectives of dam and Numbers of dam

The Figure 04 shows the functions and effects of dams in Japan. Accordingly some dams have been built with the view of flood control only, while some dams have been constructed with the aim of flood control and water utilization, and some have been built with the view of water utilization only.

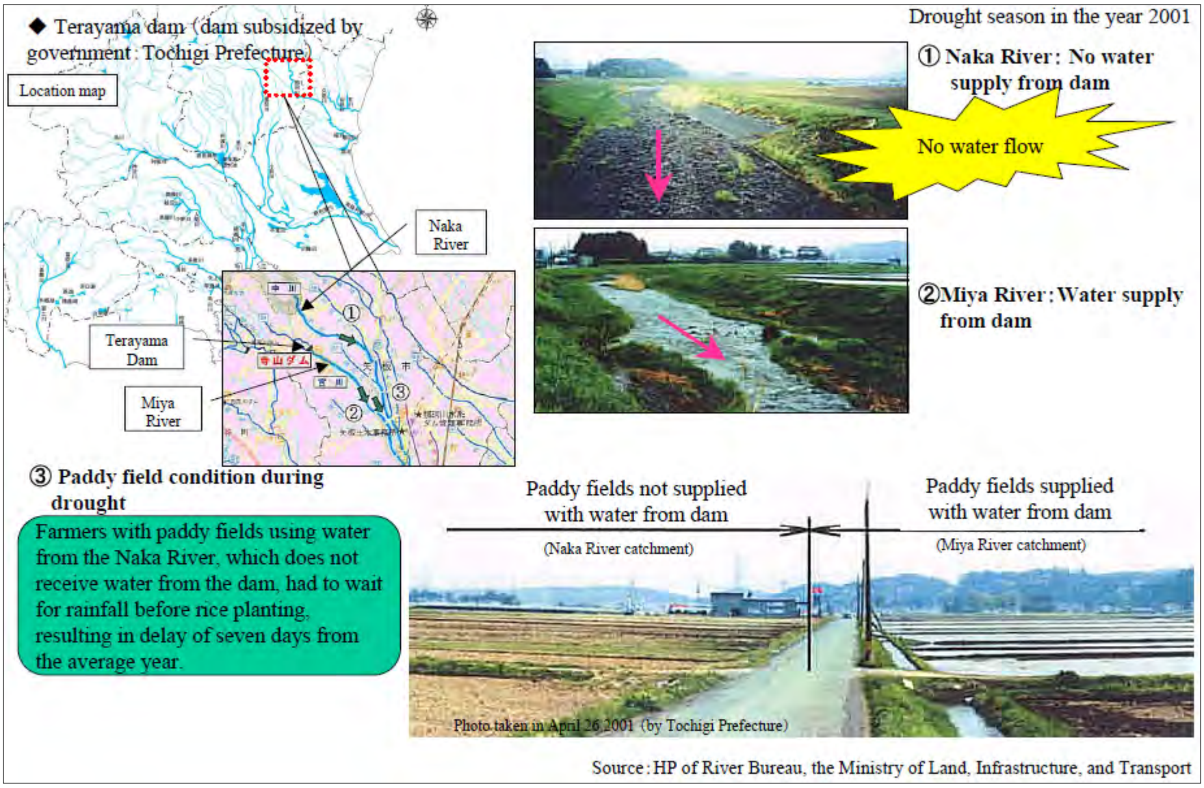


Figure 05: Effects of dams in drought condition

The Figure 05 shows the effects of dams in drought conditions. Accordingly the paddy fields can be cultivated only in the Miya river catchment with the water supply by dam. In Naka River catchment the paddy field were not able to cultivate at that time with having no water supply dam.

Having faced to the drought condition in 2005 as shown in Figure 03 the Japanese government took a decision to build the Sameura Dam in Yoshino River as solution to control the future impacts.

◆ **Sameura Dam**

Yoshino river basin is a one of the biggest river basins in Japan including a catchment area of 3,750 km^2 and the length of the river is 194 km while 20% of the land area of Shikoku Island included to the Yoshino River basin. There is a big difference of spread of rainfall over this area. Some parts take very high annual rainfalls while some other parts having very less rainfall. Therefore, both the floods and droughts are experience in this basin. In 1966, Yoshino River Development project was launched and completed in 1975. Under that, flood control measures and water supply schemes were implemented. The major construction of this project was the Sameura Dam which was built with four purposes that are as, flood control in Yoshino River, maintenance of normal function of the river water, water supply to Shikoku four prefectures for irrigation and power generation. The Figure 06 shows the Sameura Dam.

Figure 06: Sameura dam

◆ **Donto Dam**

Donto dam in Miki City area has been constructed under the Toban-Yosui Irrigation Project. By the water diversion schemes of Donto dam, it is expected to supply water to improve the agricultural infrastructure in the field for rural development. Four cities and one town in Hyogo prefecture are benefited from this project. Irrigation water supplying to the paddy fields and tap water supplying to the urban areas are the objectives of the project. Figure 07 shows the Donto dam.

Very ancient water diversion works under the Donto dam at Inami plateau are functioning. It diverts water through four sub channels effectively. Figure 08 shows that diversion work.

In the Donto dam project area there are ponds built to supply water to the paddy fields in drought periods. These ponds have been constructed at Inami plateau. Figure 09 shows such a pond.

Figure 07: Donto dam

Figure 08: Diversion work

Figure 09: A pond

3.6 Response to Water Shortage on Agriculture

When shortages of agricultural water occur, farmers save water by means of "water-sharing (method of distributing water in accordance with designated times and turns)", intensification of repeated use and so on, though this requires a lot of labor and cost. For example, at the time of water shortage in 1994, the cost was about three times as much as that in an average year. In addition, when the whole amount of water becomes insufficient, crop growth is reduced or completely hindered.

The Figure 07 shows how the farmers tend to utilize water in a drought occasion. The farmers act to save water as much as possible changing their usual water utilization patterns. The strategies are 1) irrigation by rotation, 2) reuse of water, 3) supplementary irrigation from underground water, dead water of pond, etc., 4) sacrificing of some fields as described in the figure.

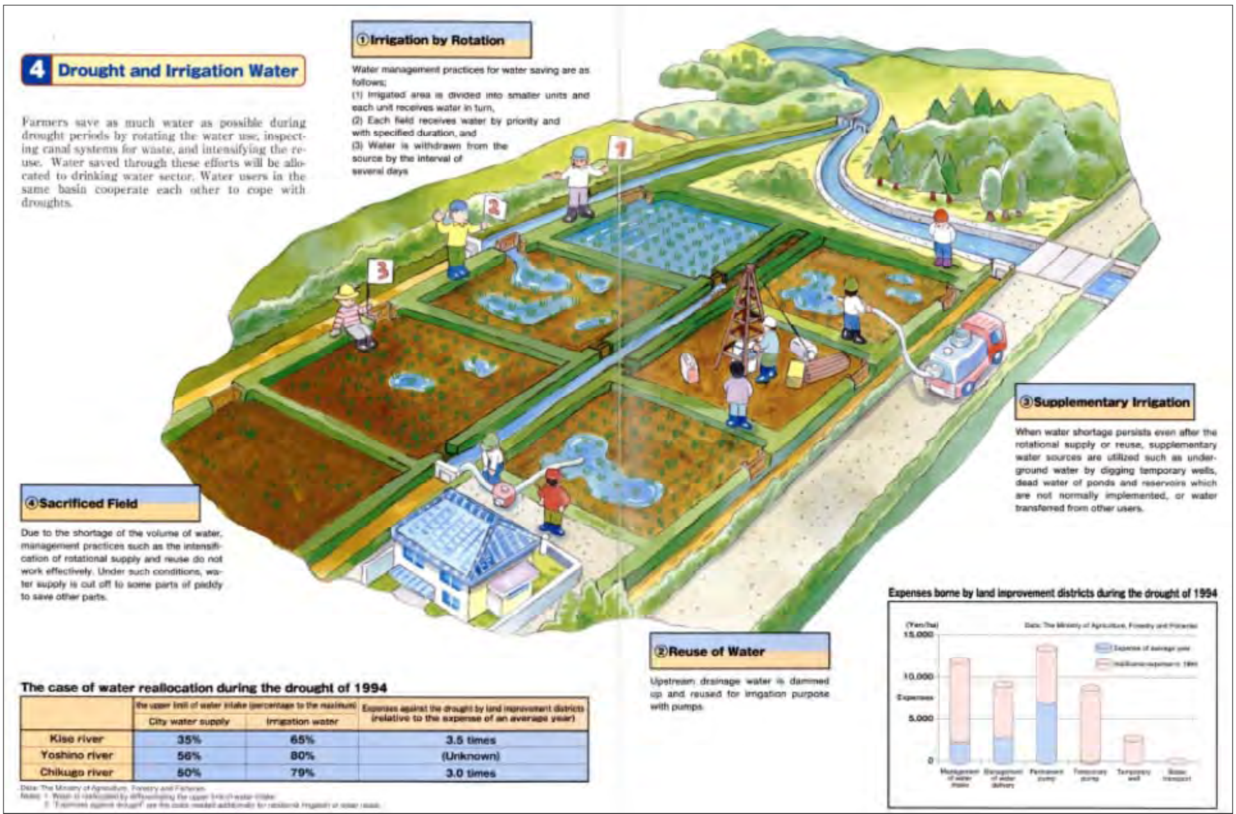


Figure 10: Strategies taken for irrigation during drought

3.7 Drought Conciliation Council for Water Use Coordination

By the river law provisions have been made for, when a severe drought happens, water users concerned first try voluntarily to adjust their water uses in principle (Art 53-1). So the consultation among stakeholders is the first measurement. In such case, river administrators shall make effort to provide necessary information for water use adjustment among water users concerned (Art 53-1). In reality, “Drought Conciliation Council”, composed of the river administrator, water users, local government, and other concerned agencies, has been established in a lot of river basins. This council has contributed to water use conciliation during droughts as a forum for mutual consultation among stakeholders. River administrators may make necessary intermediation or arbitration in case no agreement is reached in the consultation among water users (including consultation in Drought Conciliation Council). Government’s intervention is the second measurement.

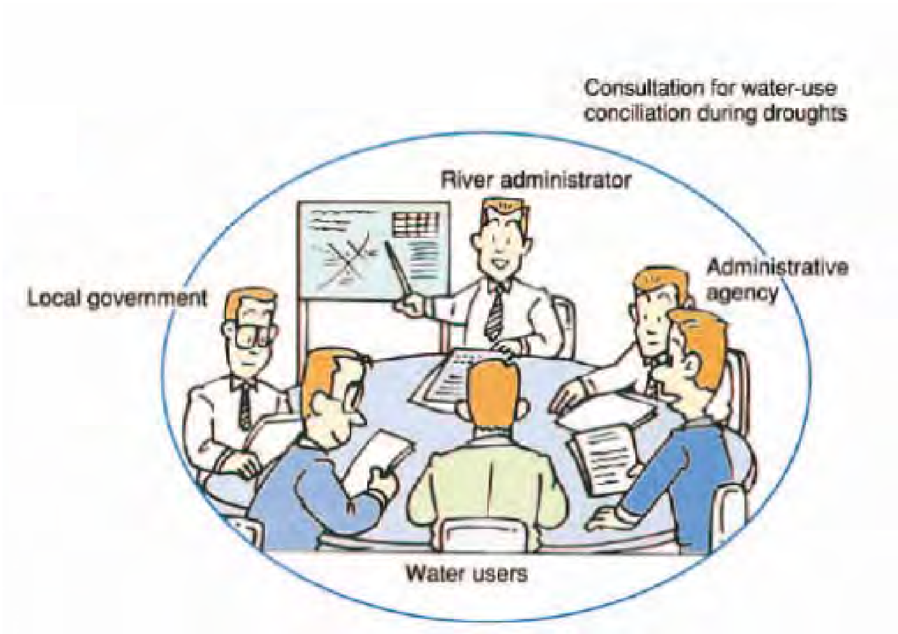


Figure 11: Drought Conciliation Council

Table1: Drought water-use conciliation councils established (as of March 2002)

Types of River System	No. of Established River Systems	No. of Established Organizations
Class A	69	103
Class B	25	25

Case Study: Ichikawa River System and Drought Management

River Basin Area: 506km^2 (Mountain: 82%, Agricultural Field: 11%, Urban Area: 7%)

Length of River: 78km (Level B River)

Utilization of Water: Irrigation (approximately 3,900ha field), Tap Water, Industrial use, and Power Generation

Dams in the river system (refer to the figure A):

Name of Dam (Year)	Managed by	Purpose	Capacity (Effective)
Kurokawa Dam (1974)	Kansai Electric Power Co. Inc.	Industrial Use, Irrigation, Tap Water, and Power Generation	21.36 million m^3
Ikuno Dam (1972)	Hyogo Prefecture	Flood Control, Industrial Use, Irrigation and Tap Water	17.0 million m^3
Hase Dam & Ota Dam (1995)	Kansai Electric Power Co. Inc.	Power Generation	8.26 million m^3 and 8.66 million m^3
Kotani Dam (2001)	Hyogo Prefecture	Tap Water and Irrigation	16.1 million m^3

Legal Framework for Water Resource Management:

Basic Policy of River Improvement of Ichikawa River System (March 2009)

*The policy was formulated by the committee composed of academic experts, engineers, representatives of people with water use rights and fishermen, and representatives of residents in the river basin areas (15 members)

-> River Infrastructure Development Plan (March 2010)

Record of Recent Water Shortage:

Year	Rate of Restriction (Maximum, %)			Number of restriction days (days)
	Tap Water	Industrial Use	Irrigation	
1994	30	90	50	112
2000	15	50	50	30
2002	20	50	50	115
2007	10	35	25	54

Water Rights for Ichikawa River:

[Ichikawa River System]

Permitted Water Rights*: Tap Water 5, Industrial Use 6, Power Generation 7, Miscellaneous 1, and Irrigation 30

Customary Water Rights*: Irrigation 518 (Total 5,829.26 ha)　*Note: Some are not in use*

[Ichikawa Mainstream]

Permitted Water Rights*: Tap Water 5, Industrial Use 3, Power Generation 3, Miscellaneous 1, and Irrigation 16 (Total 1,844.3 ha)

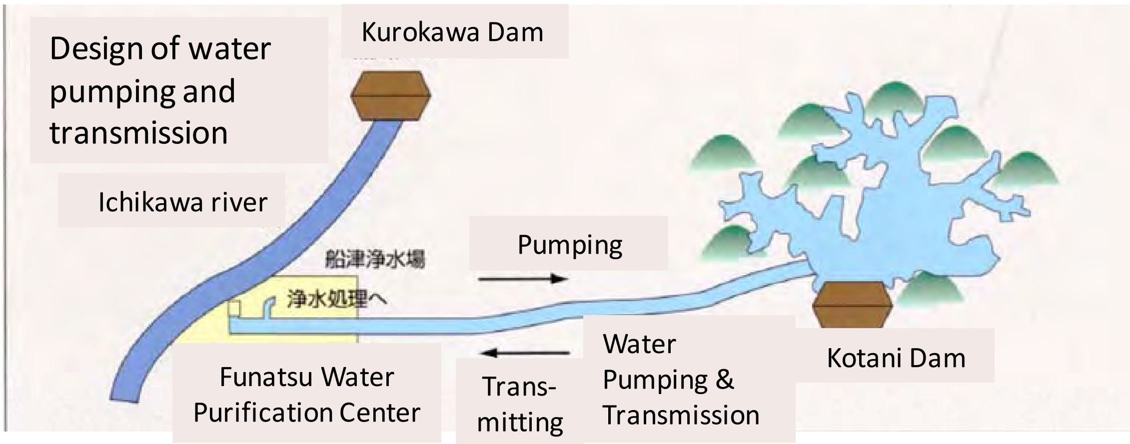
Customary Water Rights*: Irrigation 23 (Total 1,488.6 ha)

Note: In Japan, water right is defined, as "Right to use river water" under the River Law or other legislature does not provide the explicit definition of water right. The effects of water right are: 1) Water right holders can use a definite amount of water exclusively in line with the purpose of use approved by river administrator, and 2) Water right holders protected from other water use which prejudice their water rights.
Basically, in order to acquire the water right, we have to obtain the permission from river administrator. This is called "permitted water right". However, as mentioned after, it is not necessary to obtain the permission with regard to customary water right. The contents of water rights are decided on the basis of: 1) As to permitted water right, the conditions added by river administrator with the water permission, and 2) As to customary water right, the customs approved by societies.

Kotani Dam for Effective Water Resource Utilization:

In case of High Quantity of Water Flow -> Pumping from the River and Storage

Low Quantity of Water Flow -> Use Dam Water for Additional Water Supply



After completion of the construction of the Kotani Dam, no serious water shortage has been occurred in the area.

Figure A: Dams for Ichikawa River System

Regional Network for Effective Water Resource Utilization:

CHAPTER 04 – DROUGHTS IN SRI LANKA

4.1 Introduction

Low rainfall during monsoons is the cause for droughts in south-eastern, north-central and north-western areas of Sri Lanka sometimes experiencing consecutive droughts making lasting impacts on livelihoods. Droughts of serious nature occur once in about 3-4 years and severe droughts of national significance once in about 10 years also impacting hydro-power generation - the main source of energy in Sri Lanka affecting the economy. Major droughts have experienced during the years 1935-37, 1947-49, 1953-56, 1974-77, 1981-83, 1993-94, 2000-01 and 2003-04 (DMC 2005). The Figure 12 shows the drought affected areas in Sri Lanka. According to that the Kurunegala District being the first most affected district, Anuradapura, Puttlam, Badulla, Monaragala and Hambantota had been the second highest level in drought occurrence. The Figure 13 shows the general trend line of drought occurrences from 1974 to 2007. According to that the biggest drought has been occurred in 2001.

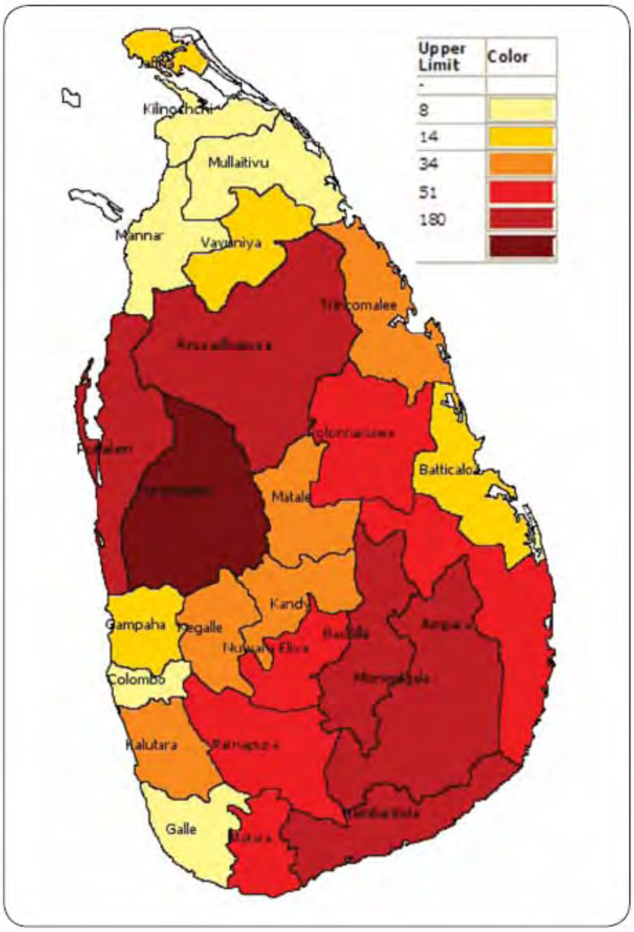


Figure 12: Drought affected areas in Sri Lanka

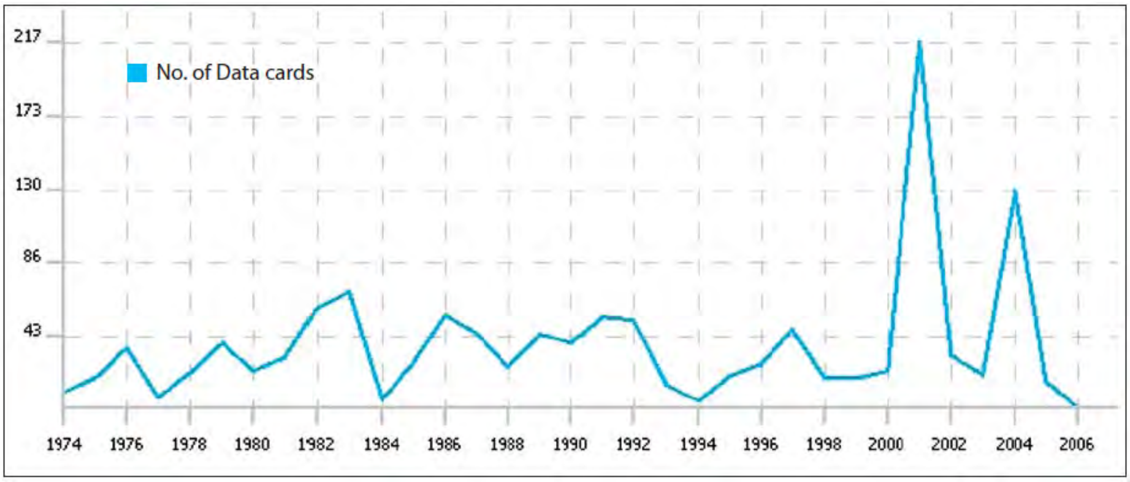


Figure 13: Drought occurrence in Sri Lanka from 1974 to 2006

4.2 Impacts on Paddy and Other Crops by Droughts

According to the data from 1974 - 2007 the highest damage caused to paddy and other crops were by occurrence of droughts. A land area of 530,685 hectares of paddy and other crops had been destroyed by droughts. Also for the period 1974-2007, the largest proportion of emergency assistance has been spent on droughts, followed by floods, cyclones, the tsunami, epidemics, coastal erosion and landslides. Emergency supplies worth Rs. 1,110,434,179 have been spent on droughts, Rs. 636,614,913 on floods, Rs. 223,520,392 on cyclones, Rs. 31,180,200 on the tsunami, Rs. 24,647,000 on epidemics, Rs. 18,620,429 on coastal erosion and finally Rs. 15,350,969 on landslides.

4.3 Drought Mitigation Measures in Sri Lanka

Droughts had been occurring for a long time in Sri Lankan history. The major project to mitigate such droughts had been implemented under the King's ruling period that is the "Village Tank Cascade System". A 'cascade' is defined as 'a connected series of village irrigation tanks organized within a micro-(or meso-) catchment of the dry zone landscape, storing, conveying and utilizing water from an ephemeral rivulet' (Madduma Bandara 1985). The village tank cascade systems were the need for a sustainable irrigation and water management technology to meet the challenge of recurrent water shortages and drought conditions in a seasonally dry environment. Therefore, it was the need for more economical and rational use of water that leads to the development of the recycling or re-uses principle. The Figure 10 shows the distribution of tanks in drought affected areas in the country.

Some of these small tanks have already been filled with sediments and not properly functioning. The government of Sri Lanka has taken steps to remove the sediments and make them again function properly. The Figure 14 shows one of such project implemented by the Disaster Management Centre in Galagamuwa Divisional secretary division, Kurunegala District. By this project, four small tanks, which have poor catchments, water is diverted from a tank which has a rich catchment. Likewise, many projects are presently operating in Sri Lanka diverting water to tanks which have poor natural intakes.

Besides to the small tank cascade development projects, the government of Sri Lanka has been built many big reservoirs and dams to supply water to drought affected areas. The Kalawewa (Anuradapura District), the Rajanganaya wewa (Anuradapura District), Minneriya wewa (Polonnaruwa District), Parakrama Samudraya (Polonnaruwa District), are some examples for such major reservoirs and dams built to mitigate the droughts.

Above mentioned irrigation systems as well as dug wells, deep wells, tube wells and drip irrigation systems have been promoted to mitigate the droughts in Sri Lanka. New crop varieties which are adopted to droughts have also been introduced as drought mitigation measures.

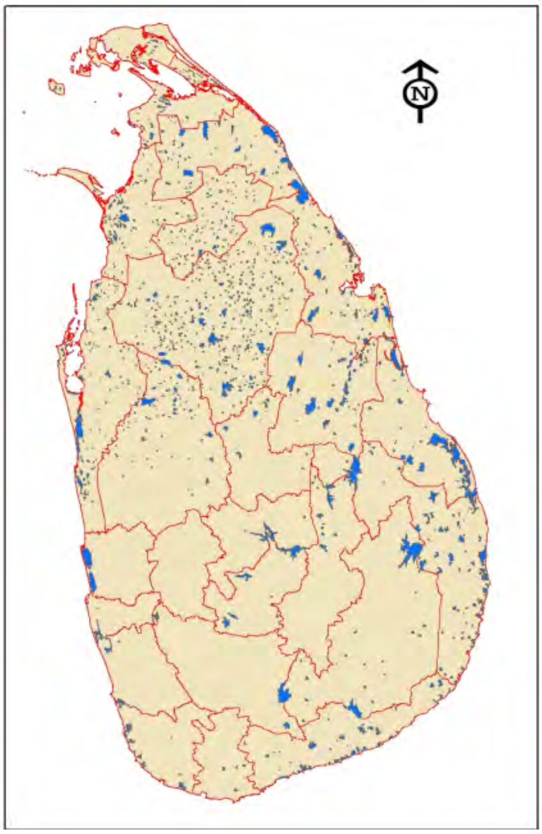


Figure 14: Distribution of tanks

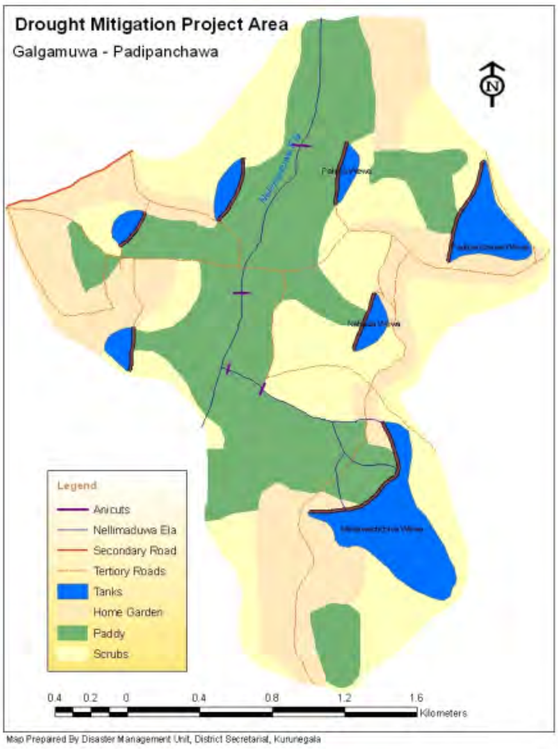


Figure 15: Drought Mitigation Project

CHAPTER 05 - CONCLUSION AND RECOMMENDATION

5.1 Conclusions

1. Dam constructions to distribute water to drought affected areas can be identified as the major drought mitigation practice in Japan.
2. These dams have been constructed through the main rivers and with high technology.
3. Most of the drought affected areas in the country have been able to provide irrigation water by these dams.
4. Because of the very steep slopes from mountains to the sea within a short distance the Japan has constructed many of dams for both to control the floods as well as to mitigate the droughts.
5. The “River Act”, some other relevant acts and regulations provide the legal base to function the dams and irrigation systems in proper.
6. Central Government, Prefectural Governments and Municipalities have a specified role in their contexts on dams and irrigations and they do it.
7. The community has organized to respond to droughts.
8. When shortages of agricultural water occur, farmers save water by means of "water-sharing (method of distributing water in accordance with designated times and turns)", intensification of repeated use.
9. “Drought Conciliation Council” has contributed to water use conciliation during droughts as a forum for mutual consultation among stakeholders.

5.2 Recommendations

1. A lot of practices of drought mitigation in Japan have already been applied in Sri Lanka
2. Several major dams have been constructed to irrigate the drought affected areas in Sri Lanka and they are quite success for long. But lot of excess water from many rivers flows to the sea and the possibilities of them should be studied to feed dam reservoirs to irrigate the drought affected areas so far. Appling the Japanese technology in this regard will be more important.
3. In Sri Lanka there are no such short distance steep slopes as mentioned above, instead, there are lot of plane areas and the lot of small and medium scale tanks.

This cascade system should be developed with the technical support of the Japan.

References:

1. http://www.mlit.go.jp/tochimizushigen/mizsei/water_resources/contents/issues.html
2. http://www.unesco.org/water/wwap/wwdr/wwdr2/case_studies/pdf/japan.pdf
3. http://www.idi.or.jp/library/pdf/RIVERE.PDF
4. http://www.narbo.jp/narbo/event/materials/twwa03/tw03_09_01-1.pdf
5. http://www.mlit.go.jp/tochimizushigen/mizsei/water_resources/contents/current_state.html
6. http://www.mlit.go.jp/river/trash_box/paper/pdf_english/36.pdf
7. http://damnet.or.jp/cgi-bin/binranA/Syuukei.cgi?sy=moku1kei
8. http://www.preventionweb.net/english/professional/news/v.php?id=12542
9. http://management.kochi-tech.ac.jp/PDF/IWPM/IWPM_Jayawardane.pdf
10. http://drh.bosai.go.jp/Project/Phase2/1Documents/8_Proceeding/8_TIK6_P.pdf
11. http://www.dmc.gov.lk/A1_TechAndMitigation.htm
12. http://www.adrc.asia/nationinformation.php?NationCode=144&Lang=en&NationNum=08
13. Ministry of Land, Infrastructure, Transport, and Tourism "Water Resource in Japan in FY2011" (August 2011)
14. Ministry of Land, Infrastructure, Transport, and Tourism "Rivers in Japan" (September 2006)
15. Brochures of Himeji Public Works Office, Hyogo Prefectural Government