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Collective decision-making under drought:
An empirical study of water resource management in Japan

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Abstract

The management of common-pool resources requires collective action and cooperation, especially when resource users face extreme weather events. This study examines collective decision-making in water resource management during droughts. By focusing on the drought response by groups of water users in river basin communities in Japan, we investigate the determinants of collective decisions on water withdrawal restrictions. Our main finding suggests that water user groups are more willing to cooperate for water conservation when other water user groups in a community also cooperate. Moreover, we examine the impact of climate variability on drought management. Our findings show that drought-related weather patterns lead to more stringent water restrictions, suggesting that climate change may pose a threat to the management of the water supply.

Keywords: Common-pool resource; Collective decision-making; Cooperation; Drought; Water conservation; Japan

JEL Classification: D70; Q25; Q54

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1 Introduction

Researchers have shown that groups of individuals are capable of overcoming social dilemmas and maintaining common-pool resources (CPRs). Traditional economic theory predicts that, without government intervention or privatization, resource users who face collective action problems overuse or even exhaust their common resources. This situation eventually leads to what Hardin [11] describes as “the tragedy of the commons.” Many studies have challenged this assumption and found evidence of cooperation in the management of CPRs [18, 22]. Such evidence suggests that individuals can sustain collective action and self-organize CPRs over time. For example, theoretical work and laboratory experiments have provided explanations for cooperative action and other-regarding behavior from the viewpoint of social preferences [5, 6, 8, 9, 23]. Field studies from many parts of the world have also identified a variety of social, economic, and ecological factors that are likely to affect successful or unsuccessful CPR management [1, 2, 4, 7, 26, 28].

This paper presents an example of CPR management by focusing on river basin communities under drought conditions in Japan. Although Japan receives relatively abundant precipitation, droughts occur regionally almost every year. In the event of a drought, water users in river basin communities organize the council in order to coordinate water use and impose joint water restrictions. This unique, user-based management system for drought response in Japan provides an opportunity to explore an interesting case of CPR management.

The objectives of this study are twofold. First, we examine which factors affect collective decision-making in water resource management during a drought. While most previous CPR studies have explored the behavior of individuals to explain its impact on community resource management, our study focuses on interactions among the groups of resource users in a community and the collective decisions that these groups make in drought management. Unlike fishery or irrigation, water resource management involves several different groups of stakeholders that most likely face a dilemma in using their water resources. Given this feature of CPR management, our particular interest in this study is the ways in which cooperation is enhanced among water user groups that jointly implement water restrictions during a drought. Thus, we investigate the characteristics associated with the CPR that may affect collective decisions and promote cooperation in community drought management.

Second, our study examines the impact of weather variability on water resource management.

Climate change is now largely acknowledged as a cause of extreme weather events including drought. According to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC), it is projected that climate change will cause the frequency and duration of droughts to increase in some parts of the world by the end of the 21st century [17]. In its national plan for climate change adaptation, the Japanese government also emphasizes the impacts of drought on water use and resource management in local communities [13]. Therefore, it is important to take into account the impact of climate change in the context of drought management. The empirical model of this study allows us to investigate whether particular weather variability affects the water restrictions implemented by councils for drought response. The result is informative for allowing policymakers to understand how water withdrawals could be regulated because of climate change.

The main result of this study shows that water user groups are more likely to cooperate with regard to water conservation when other water user groups also cooperate. Thus, our finding suggests that the level of cooperation depends on other groups' cooperation in the context of drought management. In addition, our study shows the effects of climate variability on drought response. We find that the drought-related precipitation patterns used in our analysis are correlated with water restrictions. This finding suggests that climate change may cause water resource management problems for a community.

The remainder of the paper is organized as follows. The next section presents an overview of the drought situation in Japan and the responses of local communities during a drought. The hypotheses of the study are also presented in this section. Section 3 describes the data used in our empirical analysis. Section 4 shows the results, and Section 5 concludes.

2 Background

2.1 Drought in Japan

Despite relatively abundant rainfall and annual typhoons, Japan experiences droughts, as in many other parts of the world. Almost every year, droughts occur in various parts of Japan, resulting in water shortages in local communities. Drought-vulnerable areas are located mostly in the central and western parts of the country, including Tokyo and many other cities with large populations and economic power. Table 1 provides details of the most severe droughts that have occurred in Japan during the past 50 years. The table shows droughts by year, together with

Table 1. Major severe droughts in Japan

Year	City	Mandatory restrictions on domestic water use	
		Duration (days)	Period
1964	Tokyo	84	July 10 - Oct. 1
1967	Kitakyushu	130	June 19 - Oct. 26
	Chikushino	22	Sept. 5 - Sept. 26
	Nagasaki	72	Sept. 25 - Dec. 5
1973	Matsue	135	June 20 - Nov. 1
	Otake	49	July 27 - Sept. 13
	Takamatsu	58	July 13 - Sept. 8
	Naha etc.	239	Nov. 21 - Sept. 24, 1974
1978	Osaka etc.	161	Sept. 1 - Feb. 8, 1979
	Kitakyushu	173	June 8 - Dec. 11
	Fukuoka	287	May 20 - Mar. 24, 1979
1987	Tokyo etc.	71	June 16 - Aug. 25
	Gamagori etc.	274	Aug. 24 - May 23, 1988
	Tokai etc.	188	Sept. 12 - Mar. 17, 1988
1994	Takamatsu	67	July 11 - Sept. 30
	Matsuyama	123	July 26 - Nov. 25
	Sasebo	213	Aug. 1 - Mar. 5, 1995
	Fukuoka	295	Aug. 4 - May 31, 1995
2005	Anan etc.	77	Apr. 26 - July 12
		33	Aug. 3 - Sept. 4
	Toyohashi	72	June 15 - Aug. 25
	Takamatsu etc.	78	June 22 - Sept. 7
	Yamatokoriyama	61	June 27 - Aug. 26

Source: Japanese Ministry of Land, Infrastructure, Transport, and Tourism, 2014 [16]

the names of the most affected cities. The right-hand columns present details of the mandatory restrictions on domestic water use implemented by water supply utilities. As shown in Table 1, droughts occurred locally in most cases and had severe impacts on the affected regions.

Among these extreme events, Japan suffered its worst drought in 1994. Because of the record-breaking high temperature and low precipitation, the 1994 drought caused widespread damage across the country. As a result of the restrictions placed on domestic water use, approximately 16 million people experienced mandatory cutbacks of water use [12]. The drought conditions were more severe and persisted for months in some regions, including the cities listed in Table 1. For example, the cities of Sasebo and Fukuoka in the western part of Japan adopted water use restrictions for 213 days and 295 days, respectively. The drought also had negative effects on the country's economy. In the agricultural sector, crop damage amounted to approximately 138 billion yen.[1] In the industrial sector, 77 industrial water utilities, which comprised one-third of all such utilities, curtailed water use during the drought.

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[1] One billion yen was approximately US$9.35 million at the end of 1994. Thus, 138 billion yen was approximately US$1.29 billion.

As a consequence of water shortages, firms experienced a temporal shutdown and a decline in production. Furthermore, the drought caused environmental damage to the water system such as water quality degradation in rivers and land subsidence due to excessive groundwater pumping. The experience in 1994 shows that drought can have significant social, economic, and environmental impacts.

2.2 Drought response

In terms of drought response, local communities in Japan address the issues in a unique way. When a drought occurs, the members of river basin communities bring themselves together to implement a user-based drought response. Water users, together with river administrators and government agencies, form a drought coordination council, at which they discuss water use among different user groups within the river basin. Among the actions taken in response to a drought, the council implements water restrictions to reduce water use. The interesting feature of such drought management in Japan lies in the coordination role that the council plays during a drought. The council encourages water users to engage in the decision-making process for drought management. This also means that the water restrictions implemented by the council are associated with collective action by water users in river basin communities.

The implementation of a council for drought response dates back to the 1970s. In 1974, the former Japanese Ministry of Construction issued a notification about drought management [15].[2] The notification promoted the implementation of drought coordination councils in river basin communities facing the risk of drought. Since then, communities have begun to organize councils in response to droughts. Such councils play an important role in drought management by facilitating communication and information sharing through interactions among multiple stakeholders. Although participation in the council depends on the community in question, councils generally consist of stakeholders such as water user groups (e.g., domestic and industrial water utilities, groups of farmers, electric power companies), river administrators (the Ministry of Land, Infrastructure, Transport, and Tourism, prefectures, municipalities), local prefectures and municipalities, and other related administrative agencies (Japan Water Agency, the Ministry of Land, Infrastructure, Transport, and Tourism, the Ministry of Agriculture, Forestry, and Fisheries, the Ministry of Economy, Trade, and Industry).

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[2] The Ministry of Construction, together with the National Land Agency, the Hokkaido Development Bureau, and the Ministry of Transport, was reorganized into the current Ministry of Land, Infrastructure, Transport, and Tourism in 2001.

The origin of drought coordination councils may also date back to the River Act established in 1964.[3] Article 53 of the River Act provides for the coordination of water use during a drought. According to Article 53, water users shall hold consultations in order to coordinate water use among users in circumstances whereby a drought hinders water utilization. Water users are also required to respect each other's water use with regard to the aforementioned water use coordination. Thus, the law not only encourages collective action but also promotes a specific attitude among water users toward drought management. Further, Article 53 specifies the roles of water users and river administrators in drought management. While water users coordinate water use during a drought, river administrators may assist water users in reaching agreements as necessary. This implies that water users should play a major role in the decision-making process, whereas river administrators should act as mediators. Based on these provisions in the River Act, river basin communities can conduct self-organized drought management.

In the drought coordination council, participants make collective decisions on water restrictions as an important component of their drought response actions.[4] Specifically, water users impose rates of reduction on water withdrawals from upstream dams. In cases of multipurpose dams that provide water for domestic, agricultural, and industrial water uses, these restriction rates are implemented simultaneously for each type of water use. Figures 1a and 1b present the restriction rates of the water withdrawals associated with domestic, agricultural, and industrial water in each drought that occurred in Japan between 1983 and 2013. Figure 1a compares the water restriction rates for domestic and agricultural water. In some cases, the same restriction rates are applied to these water uses. In other cases, however, different restriction rates are applied to each type of water use. A similar tendency is observed when comparing domestic and industrial water restriction rates, as shown in Figure 1b. These restriction rates do not originate from individual decisions by each water user group, but from the collective decisions of the drought coordination council. In other words, water user groups act together to curtail water use as a part of their response to a drought. Hence, the drought coordination council implements water restrictions as a result of collective decision-making by water user groups.

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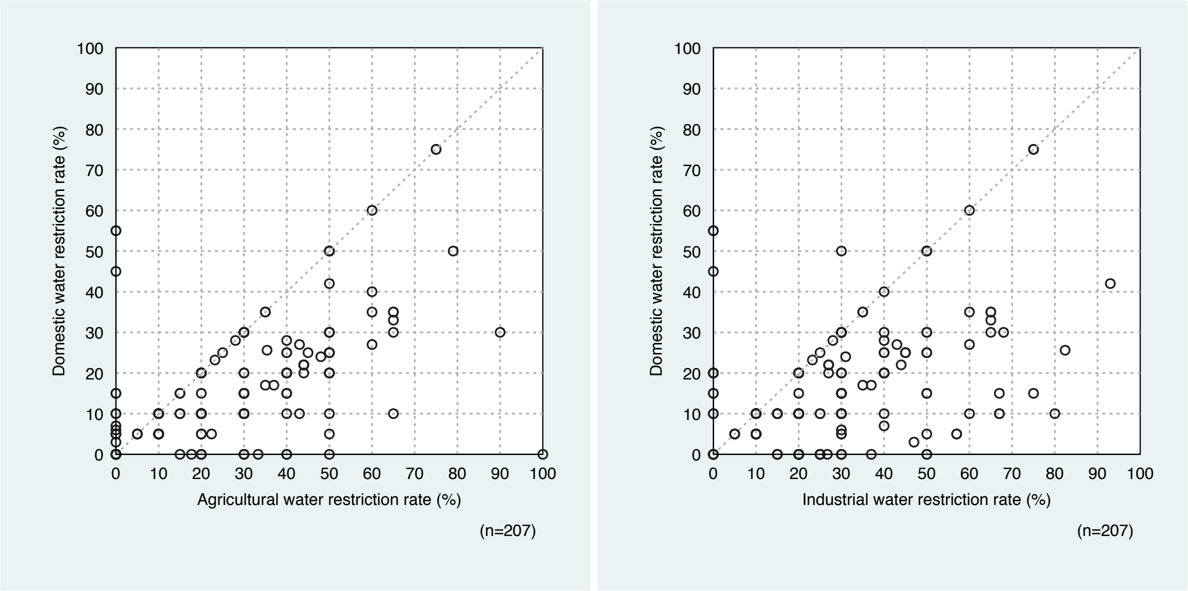
[3] The former River Act, which had lasted since 1896, was replaced by the 1964 River Act. A major amendment was made in 1997.

[4] Note that the water restrictions introduced in this section are different from the mandatory restrictions on domestic water use mentioned in Section 2.1, which were adopted by domestic water supply utilities. The restrictions explained here apply to water withdrawals from dams and rivers.



a. Agricultural and domestic water restriction rates **b.** Industrial and domestic water restriction rates

Figure 1. Water withdrawal restriction rates

2.3 *Hypotheses*

Our study focuses on water restrictions during a drought. It examines the collective action of water user groups in river basin communities when they impose restrictions on water withdrawals from upstream dams. As mentioned in Section 2.2, water user groups from different sectors jointly implement water withdrawal restrictions. In such situations, collective action for drought management should require cooperation among water user groups. In this study, we assume that water restrictions reflect the level of cooperation for water conservation, given that the severity of the drought is controlled for. Building upon this assumption, we analyze the characteristics related to the resource systems that may affect the implementation of water restrictions. Thus, the hypotheses of this study are as follows:

H1. A water user group cooperates more for water conservation when other water user groups sharing water resources in their river basin community also cooperate.

H2. Cooperation improves when water is provided for a larger variety of purposes in a community.

H3. Communities that have longer experiences of water resource management cooperate more for water conservation.

H4. Water restrictions are less strict when a river basin community has larger reservoir storage capacities.

H1 is based on previous research on participants' behavior in CPR management [3, 7]. Cavalcanti et al. [3], for instance, examine the effect of contributions by others on one's willingness to contribute to the management of more sustainable fisheries. They find that participants are more willing to contribute to the implementation of management proposals when they believe that others also contribute. This finding suggests that many fishers are conditionally cooperative; in other words, people increase their level of cooperation as others cooperate more [10]. Evidence of such behavior is also shown in the study by Fehr and Leibbrandt [7], who conduct field experiments in fishing communities. Their results, derived from public goods games, suggest that the level of contribution depends on how much a fisher expects other fishers to contribute. In the context of our study, evidence of conditional cooperation should be found if a water user group cooperates with other water user groups, provided that these groups also cooperate.

H2-H4 examine the characteristics of the resource system that might be important for successful CPR management [21]. In this study, we use the attributes of dams as the characteristics because water user groups share water resources from dams located upstream in the river basin. H2 is included to investigate the effect of group size. Larger groups often cause collective action problems because of the higher transaction costs of reaching agreements and monitoring each other's behavior [4, 28]. For example, Cox and Ross [4] find that smaller irrigation communities are associated with better crop production. However, as Ostrom [21] points out, the way in which group size affects the interactions and outcomes of CPR management depends on the resource systems and their contexts. With regard to dam management, dams provide water resources for various purposes. The management of multipurpose dams involves more stakeholders with different resource use interests. In the event of a drought, each water user group sharing water from the same reservoir must take into account other groups in regard to water use. In addition, free-riding is less likely to occur in our case because water users collectively curtail water withdrawals by imposing restrictions via the council. Thus, we hypothesize that more purposes may lead to cooperation among water user groups in order to prevent water shortages.

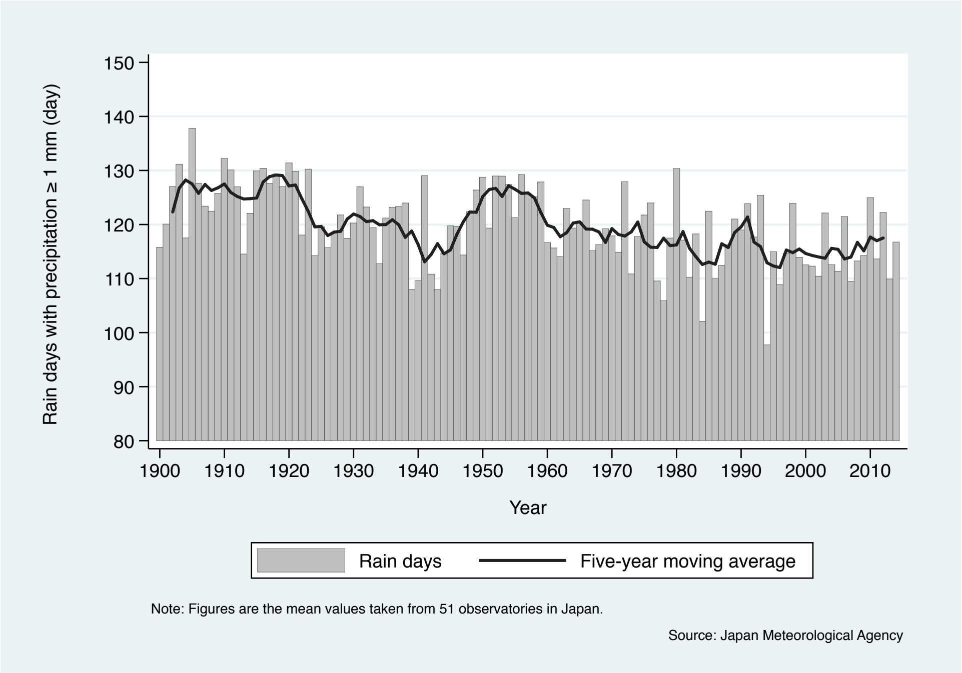
H3 focuses on the relationship between resource use and users. Through the longer experiences of using and managing a common property, members of communities can build trust and learn about the resource system on which they depend [20]. Consequently, these factors could contribute to cooperation among users, thereby leading to successful CPR management. Moreover, the reason for this hypothesis lies in the drought coordination council discussed in Section 2.2. The council provides water user groups with opportunities for communication and discussion to coordinate water use during a drought. In the context of CPR management, face-to-face communication affects collective action in a way that enhances cooperation among resource users [19]. This is because such interactions enable resource users to adopt joint strategies to pursue the optimal outcomes. Further, communication helps resource users develop norms and shared values [20]. Thus, longer experiences of water resource management may have a positive impact on cooperation during a drought.

H4 is related to the physical characteristics of the resource system that may affect water resource management. Intuitively, if a larger amount of water is regularly stored in a reservoir, communities would be able to maintain their regular water use and be less affected by a water shortage when a drought occurs. In other words, communities with greater reservoir storage capacities are less vulnerable to drought. Therefore, the severity of water restrictions should be smaller for larger reservoir storage capacities.

To examine the hypotheses above, we should control for the severity of drought in the estimation. Therefore, we include one of the following climate variables related to drought: the number of dry days, the precipitation ratio, and annual precipitation. The coefficients of these meteorological variables can be interpreted as how communities respond to climate change in the management of water resources under drought conditions. Thus, we propose the fifth hypothesis:

H5. Climate variability has an adverse effect on the management of water resources.

Climate variability and further climate change alter global and regional weather patterns, causing more frequent and severe droughts. In particular, changes in precipitation patterns directly affect drought conditions. Figure 2 gives an example of such changes in Japan. The figure shows that the annual number of rainy days, which are days with a precipitation amount of more than 1 mm, has decreased in recent decades. In other words, the number of dry days is increasing over time, implying that the duration of dry periods is also increasing. The current trend is likely to continue because the number of dry days in Japan is projected to increase [14]. Indeed, Japan may face more severe droughts in the coming years.



Note: Figures are the mean values taken from 51 observatories in Japan.

Source: Japan Meteorological Agency

Figure 2. Annual days of rain in Japan

As climate change becomes a growing concern, all levels of government have been implementing adaptation strategies to reduce vulnerability and build adaptive capacity to climate change. In November 2015, the Japanese government released its *National Adaptation Plan* to address a wide range of environmental and socioeconomic issues associated with climate change [13]. In this report, droughts are raised as one of the major concerns for the country's water resource management. Because of climate change, the frequency, intensity, and duration of droughts are projected to increase. Therefore, the effect of climate variability should be taken into account to address drought.

3 Empirical Analysis

3.1 Data

This section presents the variables used in our empirical analysis. To test the hypotheses, we use the water restriction rate for domestic water as the dependent variable. The independent variables and corresponding hypotheses are: the other two types of water restriction rates (H1), the number of purposes of a dam (H2), the operation period of a dam (H3), the reservoir capacity of a dam (H4), and the three types of climate variability (H5). We also include four control variables that are categorized into two groups: dam management characteristics and domestic water user group characteristics. Table 2 describes the variables used in our analysis

Table 2. Variable descriptions and expected effects

Variable	Description	Expected effect
Domestic water restriction rate	Water withdrawal restriction rate for domestic water	N/A
Agricultural water restriction rate	Water withdrawal restriction rate for agricultural water	+
Industrial water restriction rate	Water withdrawal restriction rate for industrial water	+
Purposes of dam	Number of purposes for which a dam provides water resources	+
Dam operaion	Operation period of a dam: number of years after the construction of a dam at the time a drought occurred	+
Reservoir capacity	Reservoir capacity for operating purposes	-
Dry days	Annual number of days with precipitation of less than 1 mm	+
Precipitation ratio	Ratio of annual precipitation to the mean annual precipitation from 1981 to 2010	-
Precipitation	Amount of annual precipitation	-
Multiple dams	Dummy variable, water restrictions are jointly implemented on water withdrawals from multiple dams: 0 = no, 1 = yes	+
Full Plan	Dummy variable, the river basin in which a dam is located is subject to the national government policy for water resources: 0 = no, 1 = yes	+
Domestic water distribution	Average daily amount of water distribution among domestic water users	-
Domestic water price	Price of domestic water charged per 10 m^3 for bore diameters of 13 mm	-

and summarizes the expected effect of each variable on the domestic water restriction rate. Table 3 provides descriptive statistics of these variables.

The primary variables of interest in this study relate to collective decisions on water restrictions during droughts. These variables are the *domestic water restriction rate*, *agricultural water restriction rate*, and *industrial water restriction rate*. As described in Section 2.2, water user groups that share the same water resource jointly implement restrictions by imposing rates of reduction on water withdrawals from dams. They set restriction rates for each type of water supply via collective decisions made by the drought coordination council. The data on water restrictions were collected from the annual report, *Water Resources in Japan*, published by the Japanese Ministry of Land, Infrastructure, Transport, and Tourism. From this data source, we were able to obtain records on regional droughts in Japan for a 30-year period from 1983 to 2013. Among more than 400 available cases, we use 207 cases of water restrictions for multipurpose dams that supply water for domestic, agricultural, and industrial uses. The descriptive statistics in Table 3 show that the mean restriction rate for domestic water is 16%. The mean restriction rates for agricultural and industrial water are greater than those of domestic water, 26% and 27%, respectively.

The variables used to test H2-H4 are related to the characteristics of resource systems. Data on these variables were obtained from the *Dam Yearbook*, published by the Japan Dam Foundation. The official websites of the dams were also used as supplementary data sources. *Purposes of dam* indicates the number of purposes for which a dam provides water resources. There are eight categories for the purposes of dams in Japan, including the three types of water

Table 3. Descriptive statistics

Variable	Unit	Mean	Std. Dev.	Min	Max
Domestic water restriction rate	%	16.16	14.00	0	75
Agricultural water restriction rate	%	26.09	19.63	0	100
Industrial water restriction rate	%	27.33	19.15	0	93
Purposes of dam	purpose	4.90	1.04	3	6
Dam operation	year	27.12	9.31	2	48
Reservoir capacity	100 million m^3	1.37	2.12	0.016	19
Dry days	day	245.60	17.75	154	306
Precipitation ratio	%	90.39	19.54	49.78	206.73
Precipitation	mm	1,697.76	570.20	661	3,912
Multiple dams	dummy	0.39	0.49	0	1
Full Plan	dummy	0.68	0.47	0	1
Domestic water distribution	1,000 m^3	1,312.15	1,907.79	3	7,962
Domestic water price	yen	1,267.44	226.62	770	2100

supplies mentioned above.[5] We use multipurpose dams that have these three types of water supplies to test H1 in this study. Therefore, the minimum number of purposes is three, while the maximum number is six. On average, the dams in our sample have approximately five purposes for their water use.

We use *dam operation* to measure the operation period of dams as the variable to test H3. We calculate how many years have passed since the completion of the dam at the time each drought occurred. In our sample, the mean operation period is approximately 27 years. That is, during the sample period from 1983 and 2013, river basin communities had, on average, 27 years of dam management experience when they implemented water restrictions.

The variable that relates to H4 is *reservoir capacity*. This represents the volume of water that a reservoir can hold for operating purposes. Reservoir capacity varies widely from 1.6 million m^3 to 1,900 million m^3, depending on the dam. This is because some cases of water restrictions involve more than one dam. We calculate the total reservoir capacity in cases when water restrictions were applied to multiple dams. This difference in water management between cases that involve multiple dams and those with a single dam is also examined in the analysis, as we explain in more detail later in this section.

With regard to climate variability for H5, we examine three alternative variables associated with the severity of drought: *dry days*, *precipitation ratio*, and *precipitation*. Dry days are defined as the number of days with precipitation of less than 1 mm. A situation in which there

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[5] Besides domestic, agricultural, and industrial water supplies, other purposes of dams in Japan are controlling floods, generating hydroelectric power, stabilizing water flow, supplying water for snowmelt control, and providing facilities for recreation.

are many days without rain is likely to cause a drought and may even lead to severe conditions. Therefore, this precipitation pattern may be relevant to the level of water restrictions. We expect that more dry days exacerbate a drought, thereby resulting in the implementation of a higher water restriction rate. Another weather-related variable is the precipitation ratio. We define the precipitation ratio as the ratio of annual precipitation to the mean annual precipitation between 1981 and 2010. When there is higher precipitation compared with the average year, droughts are likely to be less severe. Thus, we expect the precipitation ratio to be negatively related to the water restriction rate. The other variable is the amount of precipitation. Since precipitation such as rain and snow contributes to the recharging of reservoirs, the amount of precipitation is likely to affect the occurrence of drought. We use annual precipitation in order to capture the overall tendency for drought severity throughout a year. We expect higher precipitation to mitigate a drought, thereby reducing the water restriction rate. The data on these meteorological variables were taken from the online database of the Japan Meteorological Agency.[6] From this database, we collected data from the available observatories that are geographically closest to each dam's location.

Our analysis includes four control variables: *multiple dams*, *Full Plan*, *domestic water distribution*, and *domestic water price*. The former two variables belong to the dam management characteristics and the latter two belong to the domestic water user group characteristics. The dummy variable *multiple dams* distinguishes joint water restrictions on multiple dams from water restrictions on individual dams. In some regions, several dams in the same river basin are managed together regularly or only during a drought. Communities in these regions convene the drought coordination council and implement joint water restrictions on their dams. We use this variable to examine the systematic difference in the collective decisions applied to multiple dams and a single dam. If water restriction rates are jointly implemented on multiple dams, the value is one; otherwise, the value is zero. The variable implies that some regions have more complex management systems in terms of collective action. Assuming that the joint implementation of water restrictions reflects the higher level of cooperation in a river basin community, we can expect a higher water restriction rate to be imposed in cases that involve multiple dams.

We also examine a variable related to the national government policy for water resource use. Governmental organizations are one of the influential factors in CPR management. Contrary

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[6] http://www.jma.go.jp/jma/indexe.html.

to the adverse impact of government interference often recognized in CPR studies, Zhang et al. [28] show the positive effects of a top-down approach on irrigation water productivity. They find that the involvement of an upper-tier water users association in farmers' crop choices leads to higher water productivity. In our study, the national government policy and the related water resource plan may help enhance drought management and promote cooperation among water users. The Japanese Ministry of Land, Infrastructure, Transport, and Tourism has designated seven river basins as "river systems for water resources development" under the Water Resources Development Promotion Law.[7] These river basins have all implemented the "Water Resources Development Basic Plan (Full Plan)." The main objective of the Full Plan is to promote the comprehensive development and rational use of water resources in each river basin. The plan is developed for each river basin by committees and working groups, where the risk of drought is taken into account to set a target for water supplies. We use a dummy variable, *Full Plan*, equal to one if a river basin under water restrictions is designated as a Full Plan area, and zero otherwise. Our intention in using this variable is to investigate whether the national government policy influences drought management in local communities. We expect higher water restriction rates for those areas that have implemented the Full Plan.

The data on domestic water user groups were obtained from the *Local Public Enterprise Yearbook*, published by the Japanese Ministry of Internal Affairs and Communications.[8] The variable *domestic water distribution* is the average amount of domestic water distribution by water utilities per day. A larger amount of water use may lead to a lower water restriction rate because of higher opportunity costs. The opportunity costs of water savings may be relatively high when the domestic water supply supports people and businesses that consume a larger amount of water. They may include various private and public service sectors such as offices, hospitals, and schools. Thus, such larger communities may prioritize domestic water by relaxing the water restrictions.

The variable *domestic water price* is measured by the price of water charged per 10 m^3 for

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[7] The seven designated river basins are the Tone River system, Ara River system, Toyo River system, Kiso River system, Yodo River system, Yoshino River system, and Chikugo River system. The designation was first applied to the Tone River system that drains in the Tokyo metropolitan area and the Yodo River system that drains in the Osaka metropolitan area, in 1962. Today, the seven river basin regions have a population of 67 million, or 52% of Japan's total population, and the value of the shipments of manufactured goods from these regions amounts to 11.1 billion yen, or 44.5% of the total value [16]. The term "river system" is used to refer to a river basin in Japan.

[8] In Japan, water utilities are run by municipalities (cities, towns, and villages), prefectures, or joint public entities consisting of municipalities and prefectures. The latter two supply water to lower-tier municipalities as wholesalers. Municipal water utilities then supply this water or water from their water sources to households.

bore diameters of 13 mm. We expect higher water prices to have a negative impact on the water restriction rate. People respond to the level of water price and reduce their daily water usage as prices rise [25]. Under such circumstances, a strict water restriction may not be implemented because water use is already restrained.

3.2 Model

We use ordinary least squares (OLS) model to examine the extent to which collective decision-making affects water withdrawal restrictions during a drought. The specification for the regression model is:

$$Y_{ij} = \beta_0 + \beta_1 X_{ij} + \beta_2 D_{ij} + \beta_3 C_{ij} + \beta_4 Z_{ij} + \delta_{ij} + \varepsilon_{ij}$$

where Y_{ij} is the maximum water restriction rate for domestic water, which is applied to dam j during drought i.[9] X_{ij} is a set of the collective decisions on the two other water restriction rates (*agricultural water restriction rate* and *industrial water restriction rate*), D_{ij} is a set of dam group characteristics (*purposes of dam*, *dam operaion*, and *reservoir capacity*), C_{ij} is a set of climate variability (*dry days*, *precipitation ratio*, and *precipitation*), and Z_{ij} is a set of control variables (*multiple dams*, *Full Plan*, *domestic water distribution*, and *domestic water price*). In addition to these variables, two types of fixed effects are included in our analysis: year fixed effects and region fixed effects, denoted by δ_{ij}. We control for either of these in the model. For the region fixed effects, we divide the country into eight areas, which is commonly used as a geographical classification in Japan. Finally, ε_{ij} is an error term. Overall, we have 207 observations, including 56 dams for the estimation. Thus, a dam in our sample experiences water restrictions approximately four times on average during the data period between 1983 to 2013.

4 Results

The results of our regression analysis are presented in Tables 4 and 5. In Table 4, we control for the year fixed effects in all models, while in Table 5, we control for the region fixed effects. One of the three climate variables is included in each model: the variable *dry days* is in models

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[9] Note that the water restriction rate is applied to "a group of dams j," when the restrictions involve multiple dams, as described in the previous section.

1 and 4, *precipitation ratio* is in models 2 and 5, and *precipitation* is in models 3 and 6. Models 1-3 in each table include *agricultural water restriction rate* and *industrial water restriction rate*.

Agricultural water restriction rate is significantly related to the domestic water restriction rate. The coefficients are positive and statistically significant at the 1% level in all models. *Industrial water restriction rate* is also significant, but only in one model; the coefficient is positive and significant in model 3 in Table 4. The positive sign of the coefficients suggests that a domestic water user group applies a higher water restriction rate as other water user groups, agricultural and industrial water user groups, increase their water restriction rates. This finding is in line with the hypothesis H1, namely, a water user group is more willing to cooperate for water conservation when other water user groups also cooperate. We find that the level of cooperation in drought management, measured by the water restriction rate, is related to other groups' water conservation efforts.

Purposes of dam is positively correlated with the water restriction rate. The coefficients are statistically significant at the 1% level in the models with the year fixed effects. In all the models using the region fixed effects, the coefficients are also significant at the 1% level, except models 1 and 3 in which the coefficients are significant at the 5% level. These results show that dams with more purposes tend to implement more stringent water restrictions. Therefore, the finding supports our hypothesis H2: the more purposes for water use lead to more cooperation. The number of purposes of a dam indicates the number of stakeholders involved in water resource management. In our study, we find that a larger group may lead to cooperation in terms of water conservation. The variable *dam operation*, measured by the operation period of a dam at the time each drought occurred, is not significantly related to the water restriction rate in our estimation. Thus, we do not find evidence of the hypothesis H3: a longer experience of resource management induces cooperation for water conservation. We find a positive and significant correlation between *reservoir capacity* and the water restriction rate. The coefficient of 0.707 in model 1 in Table 4 suggests that an increase in reservoir capacity by 100 million m^3 raises the domestic water restriction rate by approximately 0.71%. This result is contrary to H4 and suggests a positive impact of reservoir capacity on the water restriction rate. One possible explanation for this is that reservoir capacity as a characteristic of CPRs may promote cooperative action toward water saving. Schlager et al. [24] describe the storage capacity of a resource system as one of the physical aspects of CPRs, which induces cooperation

Table 4. Regression results (OLS, year fixed effects)

Dependent variable	Domestic water restriction rate					
	1	2	3	4	5	6
Agricultural water restriction rate	0.438*** (0.088)	0.421*** (0.087)	0.413*** (0.075)			
Industrial water restriction rate	0.063 (0.064)	0.079 (0.064)	0.096* (0.054)			
Purposes of dam	3.186*** (0.715)	2.929*** (0.695)	2.325*** (0.710)	3.760*** (1.111)	3.669*** (1.058)	3.043*** (1.115)
Dam operation	-0.026 (0.096)	-0.031 (0.096)	0.049 (0.111)	0.093 (0.123)	0.099 (0.120)	0.171 (0.137)
Reservoir capacity	0.707* (0.378)	0.586 (0.367)	0.328 (0.328)	0.586 (0.579)	0.596 (0.560)	0.263 (0.502)
Dry days	0.092** (0.039)			0.061 (0.059)		
Precipitation ratio		-0.020 (0.052)			-0.113* (0.065)	
Precipitation			0.008*** (0.002)			0.008*** (0.003)
Multiple dams	-2.931 (1.845)	-2.645 (1.861)	0.929 (2.045)	-10.407*** (2.185)	-9.960*** (2.145)	-6.596*** (2.399)
Full Plan	9.647*** (1.938)	9.767*** (1.953)	8.697*** (1.768)	6.951*** (2.325)	7.428*** (2.383)	6.231*** (2.207)
Domestic water distribution	-0.000 (0.000)	-0.000 (0.000)	0.001 (0.000)	-0.000 (0.001)	-0.000 (0.001)	0.000 (0.001)
Domestic water price	0.001 (0.005)	-0.001 (0.005)	-0.001 (0.005)	0.006 (0.006)	0.005 (0.006)	0.005 (0.005)
Constant	-50.578*** (13.828)	-22.694*** (7.404)	-34.649*** (7.708)	-38.427* (20.333)	-12.582 (9.256)	-30.102*** (9.049)
Observations	207	207	207	207	207	207
Adjusted R^2	0.486	0.478	0.533	0.196	0.204	0.247

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

among resource users when managing their resources.[10] The presence of storage capacity helps mitigate the problems that arise in CPR settings. For example, storage capacity restrains the overconsumption of resources when users attempt to withdraw or harvest the resources before others do. This means that resource users' incentives for overuse become lower because they can reserve their resources. Taking the example of an irrigation system, Schlager et al. [24] point out that larger storage capacities enhance users' ability to control water. They further argue that users who have more ability to control water through storage capacity are more cooperative in managing water resources.

The estimated results of the meteorological variables suggest that climate variability can

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[10] According to Schlager et al. [24], *storage* is defined by the availablity of storage capacity (e.g., reservoirs, irrigation canals, and groundwater basins) that is able to keep resource units (e.g., water in stream, fish, and wildlife) in stock. The other physical aspect, *stationarity* or *mobility*, is defined by whether unharvested resource units (e.g. water, shellfish, and timber) remain spatially for a longer time, or migrate inside and/or outside the resource system.

Table 5. Regression results (OLS, region fixed effects)

Dependent variable	Domestic water restriction rate					
	1	2	3	4	5	6
Agricultural water restriction rate	0.524***	0.517***	0.511***			
	(0.085)	(0.086)	(0.086)			
Industrial water restriction rate	-0.012	-0.017	0.029			
	(0.074)	(0.072)	(0.072)			
Purposes of dam	2.161**	2.258***	1.804**	3.608***	3.282***	3.000***
	(0.831)	(0.801)	(0.738)	(1.057)	(0.991)	(1.016)
Dam operation	0.084	0.093	0.085	-0.012	0.067	0.004
	(0.100)	(0.104)	(0.101)	(0.101)	(0.099)	(0.103)
Reservoir capacity	1.090***	1.142***	0.850***	1.313*	1.251**	1.038*
	(0.348)	(0.323)	(0.278)	(0.672)	(0.574)	(0.606)
Dry days	-0.014			0.100		
	(0.048)			(0.069)		
Precipitation ratio		-0.023			-0.160***	
		(0.032)			(0.044)	
Precipitation			0.004***			0.001
			(0.001)			(0.002)
Multiple dams	-2.747	-2.854	-0.953	-10.894***	-11.009***	-10.557***
	(2.025)	(2.064)	(2.252)	(2.284)	(2.218)	(2.579)
Full Plan	8.039***	8.120***	8.236***	7.033**	7.396***	6.602**
	(2.227)	(2.249)	(2.197)	(2.907)	(2.825)	(2.838)
Domestic water distribution	-0.002**	-0.002**	-0.001**	-0.002*	-0.002*	-0.002*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Domestic water price	-0.004	-0.003	-0.006	0.001	0.001	-0.002
	(0.004)	(0.004)	(0.004)	(0.005)	(0.005)	(0.005)
Constant	-12.494	-14.225*	-17.767**	-40.650**	-5.818	-17.621*
	(14.580)	(7.340)	(6.914)	(19.880)	(10.640)	(10.076)
Observations	207	207	207	207	207	207
Adjusted R^2	0.558	0.558	0.578	0.184	0.222	0.177

Robust standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

lead to more stringent water restrictions. The coefficients of *dry days* and *precipitation ratio* are in line with H5, showing a significant correlation between each weather variable and the water restriction rate. The coefficient of *dry days* in model 1 in Table 4 indicates that one fewer rainy day raises the water restriction rate by approximately 0.09%. This finding implies that water restrictions can be more serious when there are more dry days. As mentioned in Section 2.3, the number of dry days has increased in Japan over the past 100 years and this trend is expected to continue. The Japanese Ministry of the Environment and the Japan Meteorological Agency have jointly reported climate change projections for assessing the impact of climate change on the country in order to develop the *National Adaptation Plan* [14]. According to their report, the number of dry days in Japan is projected to increase by 1.1 days (RCP2.6) to 10.7 days (RCP8.5) based on representative concentration pathways (RCPs).[11] By using these projections and our

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[11] RCPs are the climate scenarios adopted in the IPCC Fifth Assessment Report. Four RCPs are commonly used and defined by the total radiative forcing by 2100. RCP2.6 represents the least radiative forcing level pathway and RCP8.5 represents the highest level pathway.

estimated result, the water restriction rate is expected to rise by 0.10% to 0.98% depending on the scenarios. Hence, changes in precipitation patterns may cause more extreme droughts to occur, thereby making the drought response more difficult in terms of water restrictions. The variable *precipitation ratio*, measured by the ratio of annual precipitation to the mean annual precipitation between 1981 and 2010, is negatively correlated with the water restriction rate. The finding suggests that the water restriction rate tends to increase in a year with lower precipitation compared with the average year. The coefficients are statistically significant in model 5 in both Tables 4 and 5. The estimation results show that the restriction rate increases by approximately 0.11% to 0.16% when the precipitation ratio is 1% lower. Thus, drought management may be affected by this climate variability in the future. However, whether Japan will receive higher or lower precipitation in the coming decades is uncertain. The precipitation projections have high fluctuations depending on the scenarios and regions. Lastly, the coefficients of *precipitation* are statistically positive and significant, which is inconsistent with our hypothesis. This may be due to the unsuitability of using annual precipitation to capture the impact on water restrictions that are usually implemented for only a short period of time. Although the duration of water restrictions for each drought varies, water restrictions in some cases last only a couple of days or weeks in our sample. Therefore, the annual amount of precipitation may not reflect such short-term droughts.

Besides the hypotheses above, we also include other characteristics associated with the resource system and test whether these variables affect collective decisions on water restrictions. The variable *multiple dams* is insignificant in models 1-3 in Tables 4 and 5. On the contrary, we find that the coefficients are negative and statistically significant at the 1% level in models 4-6. The water restriction rate is likely to be lower when river basin communities manage several dams together for the purpose of drought response and the implementation of joint water restrictions on these dams. Nevertheless, this is only the case when we do not control for agricultural and industrial water restriction rates. We do not find that the joint implementation of water restrictions on multiple dams is related to the domestic water restriction rate in models 1-3. The policy-related variable, *Full Plan*, is positive and significantly correlated with the water restriction rate. The result suggests that a higher water restriction rate tends to be implemented in those river basins where the national government policy for water resources is applied. Thus, we find that the government policy for water resources is positively related to collective decision-making in community drought management. The coefficients of *domestic water distribution* are insignificant in the models using the year fixed effects. However, they are negative and statistically significant in the models using the region fixed effects. The negative sign of the coefficients suggests that a lower water restriction rate tends to be applied to domestic water user groups with higher water distribution. With regard to *domestic water price*, the coefficients are not significantly related to the water restriction rate in any of the models. We expect water prices to have a negative effect on the water restriction rate because water use may already be restrained in municipalities with higher water prices. However, we do not find a correlation between water prices and the water restriction rate.

5 Conclusions

This study examines collective decision-making in water resource management during droughts. The data used in the analysis include 207 cases of regional droughts that occurred in Japan from 1983 to 2013. In response to a drought, water users in river basin communities participate in drought management and take action to mitigate water shortages. By focusing on this community-based drought response, we examine which characteristics of the resource management affect collective decisions and contribute to cooperative actions for water conservation. In addition, our study investigates the impact of climate variability on drought management by analyzing weather patterns that are likely to affect drought conditions.

The regression results show cooperative collective action for water conservation among water user groups that jointly implement a drought response. We find that the level of water restrictions on domestic water user groups, measured by the rate of reductions in water withdrawals, is correlated with the level of water restrictions on other water user groups. Water user groups tend to impose higher water restriction rates when other water user groups also impose higher water restriction rates. This result suggests that the willingness to cooperate and save water depends on other water users' cooperativeness. This finding is in line with the results of laboratory experiments showing that people are conditionally cooperative, namely they are willing to cooperate when others cooperate as well [10]. Thus, the result of our empirical study could be concluded by saying that we find some evidence of conditional cooperation in real-world settings. Our study also shows other factors related to collective decision-making in drought management. In particular, we find that group size, measured by the number of purposes of a dam, is positively correlated with the level of water restrictions. Another finding is that greater reservoir capacity may lead to more cooperation in drought management. This result shows that the level of water restrictions is higher when the storage capacities of reservoirs, which are the source of water shared in a community, are larger.

Furthermore, we examine how climate variability affects drought management. Our study finds that drought-related climate patterns are related to water restrictions. The results show that dry days, measured by the number of days without precipitation, lead to the implementation of a higher water restriction rate. We also find that water restrictions tend to be more serious when annual precipitation is lower compared with precipitation in the average year. These findings suggest that more severe water restrictions may be required as climate change becomes more serious through changes in precipitation patterns. Given climate change as a cause of more intense and frequent droughts, our study shows the consequences that climate change may have for water resource management.

While we should bear in mind that the factors that induce successful or unsuccessful CPR management depend on the context, our findings may have important implications for policymakers, local governments, and managers. Because the community-based management of water resources involves various groups of stakeholders, it is crucial to understand the behavioral mechanisms of these groups when they interact. Our findings suggest that reciprocal cooperation could lead to greater water conservation effort during a drought. Cooperation is a key element in community resource management. From this perspective, drought coordination councils in Japan may play an important role in providing opportunities for interaction to promote cooperation among water users. Moreover, a better understanding of CPR management mechanisms may be useful in terms of climate change adaptation. We can expect more serious droughts to occur in the coming decades because of climate change. Research on water resource management by communities facing droughts could thus contribute to the implementation of effective climate change adaptation strategies.

Nevertheless, a limitation of our study is that unobserved, yet important variables may affect collective action in the context of water resource management. Indeed, analyzing the interactions of resource users and the management mechanisms of resource systems is challenging because the management of CPRs includes multiple stakeholders who form extremely complex interrelations. For example, the farmers in a community who cooperate with each other when confronting farmers in other communities may compete with each other for the allocation of water in their own community [27]. Future research should take into account such interactions among multiple levels of complex systems to examine the reality of CPR management.

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