



# The Kabu-ido system and factors affecting local groundwater extraction control: case study of a customary groundwater management in Japan

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## Abstract

In the early 1800s, a water conflict occurred in a community named the Fukuzuka Ring Levee on the Noubi Plain, Japan. Upper villages required artesian wells for irrigation and domestic uses, but lower villages did not welcome them because drainage from the wells caused impoundment damage to their paddy fields. The Kabu-ido system was a set of rules, including regulation of the number of wells per village, introduced to de-escalate the conflict. Under the system, groundwater uses were controlled not by external authority, but by the community residents themselves. This paper has two purposes. First, it reconstructs the daily operations of the Kabu-ido system, principally by referring to surviving local diaries, to describe hitherto unknown details regarding the management of groundwater by local people 200 years ago. The diaries show that well managers, selected from residents, regulated the use of wells using various tools, including permission and surprise inspection. Second, this paper evaluates to what extent self-imposed numerical regulation was successful by checking the number of wells listed in village expenditure notes. The documents indicate that regulation did not always work. The factors underlying this are considered using the analytical framework from the commons studies. Analysis shows that, while institutional arrangements of the Kabu-ido system, such as well management with keys, rules of joint responsibility, and the prohibition of indoor wells, work positively in enforcing numerical regulation by lowering the costs of monitoring for unauthorized wells, the natural characteristics of groundwater and climate conditions such as sudden drought work negatively.

**Keywords** The Kabu-ido system · Groundwater management · Commons · History · Japan

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## Introduction

Generally, in the fields of environmental and water history, surface water management has received much more attention than groundwater management (McNeill 2003; Schönach 2017). The same can be observed in water-related conflict studies at international level. Wolf (2000) showed how indigenous communities solved local water problems and considered how such methods might be applied to modern conflicts over shared water resources among nations. More recently, a growing number of papers have been published on water diplomacy, which focus on a process where a variety of stakeholders in both the public and private sectors enhance cooperation on the utilization of internationally shared water resources (Susskind and Islam 2012; Islam and Susskind 2015; Klimes et al. 2019). In both cases described above, the primary concern is international rivers, not groundwater. This major focus on surface water histories is even more true of historical studies on water issues in Japan during the Edo period (Kelly 1982; Brown 2015; Kuroishi 2020). As such, this paper provides an understudied topic, historical groundwater management in Japan.

The Kabu-ido system was a customary institution to control groundwater extraction. It was created at the end of the Edo period (1600–1867) in a community named the Fukuzuka Ring Levee on the Noubi Plain of Japan (Shimizu 2014). Although the Kabu-ido system disappeared in the 1930s, Takahashi (1973) regarded it as a pioneering example of an institution for groundwater management in Japan. Although the term “ring levee” originally referred to a levee as a physical structure or a name of a place where the levee was constructed, it finally assumed the meaning of a community that was encompassed by the levee.

As will be explained later, the Fukuzuka Ring Levee was a low-lying community on a gentle incline, composed of sixteen villages. Ten upper villages were located in an area of higher elevation and six lower villages in an area of lower elevation. In the early 1800s, the upper villages developed artesian wells for a stable water supply for irrigation and domestic uses, but this led to conflicts, because the drainage water from wells caused impoundment problems for paddy fields in the lower villages. The Kabu-ido system was a set of rules, including regulation of the number of wells per village, introduced to de-escalate the conflict. Under the Kabu-ido system, groundwater uses were controlled – not by an external authority, but by the community residents themselves. The number of wells was strictly controlled and only those who had special permission could build a well. It is worth noting that *kabu* (株) means “the privilege to do business” (Miyamoto 1977) and *ido* (井戸) means “well” in Japanese.

The Kabu-ido system has been studied, but mainly by local historians and geographers (Bekki 1932; Sakurai 1934; Katano 1941; Shimizu 2014) and, thus, it is largely unknown outside the Noubi Plain, not to mention outside Japan. These studies showed the creation process of the Kabu-ido system in a few communities (the Fukuzuka and Takasu Ring Levees), where the development of groundwater extraction and the drainage problem it caused led to the creation of the Kabu-ido system as a solution. Shimizu (2014) suggested that the Kabu-ido system had been fully discussed. However, Endo (2016) and Endo (2018) expressed doubts about this assertion. Although it is true that the creation process of the Kabu-ido system in some ring levees has been studied in depth, no previous studies have been done on how widely such institutions for groundwater management spread across the Noubi Plain. Endo (2018) surveyed the official histories recorded by the municipalities in the plain and showed that ring levees, which introduced the regulation of groundwater development, spread more widely than

previously known. Furthermore, although documenting the creation process has been an objective of studies on the Kabu-ido system, there has been little discussion as to how it operated after its creation. Endo (2016) only partially showed the operation by using descriptions from a local surviving diary called the Nishimatsu Diary.

This paper expands on previous works by Endo in two ways. First, this paper not only examines other descriptions contained in the Nishimatsu Diary, but also uses a newly discovered diary (the Tanahashi diary) and other primary sources to show in further detail how the Kabu-ido system was operated via interactions between the upper villages and the lower villages. Second, no previous works, including those by Endo, have tried to evaluate the success of groundwater use regulation. This paper considers for the first time the extent to which local people succeeded in controlling the number of wells by using descriptions from local expenditure notes. This specific source has never been used in studies of the Kabu-ido system but includes information on the number of wells that were actually drilled.

This new source allows shedding light on groundwater management in the Noubi Plain. Groundwater is typically seen as a resource which is difficult to manage. A possible reason is the invisible nature. This point is well described in the 1861 judgement of the Supreme Court of Ohio, which stated that the existence, origins, and course of groundwater are “so secret, occult and concealed, that an attempt to administer any set of legal rules in respect to them would be involved in hopeless uncertainty, and would be, therefore, practically impossible.” (12 Ohio St. 194, 1861 WL 32). Nevertheless, there have been some historical studies on groundwater management. Manuel et al. (2018) explored how groundwater development affected the creation and expansion of cities with special reference to the Qanat system. Zhang (2017) showed that the evolution of the water supply system depended on groundwater in growing urban areas of Beijing, China.

While these studies are concerned with the positive influence of groundwater development, fewer studies have paid attention to the side-effects, such as overdraft or drainage problems, much less how they were solved. Gates (2005) and Wolfe (2013) showed why overdraft began and how it proceeded with examples from the State of Arkansas, U.S.A. and the Laguna region, Mexico, respectively. However, they, like previous researchers on the Kabu-ido system, did not explain in detail how local people tackled the problem. In terms of drainage problems, Dellapenna (1991) summarized the evolution of legal rules on drainage water management, such as the common enemy rule, the natural servitude rule, and the reasonable use rule, by referring to major court decisions in the past. However, these cases were, in general, related to “diffused surface water” (water on or at surface without being in a defined body of water), rather than groundwater.

In his literature review on the field of environmental history, McNeill (2010) argued that the further from the present a topic is, the less interest environmental historians have shown. He also pointed out that previous studies that were interested in policy aspects of environmental history overwhelmingly focused their attention on cases in the twentieth century, partly because of a lack of available source materials. The problems identified by McNeill (2010) can be seen in previous works on groundwater management in another academic field: commons studies. Natural resources are managed either by governments, markets, or the users themselves. Commons studies consider institutional factors that prevent excessive development of natural resources and, in particular, natural resource management by users (Dietz et al. 2002). The commons framework is useful for analysis of the Kabu-ido system where groundwater development was controlled by the users themselves. There are case studies that apply the framework to groundwater use such as Lopez-Gunn

and Cortina (2006), Sarker et al. (2009), Boone and Fragaszy (2018). However, they all deal with cases after the mid-twentieth century.

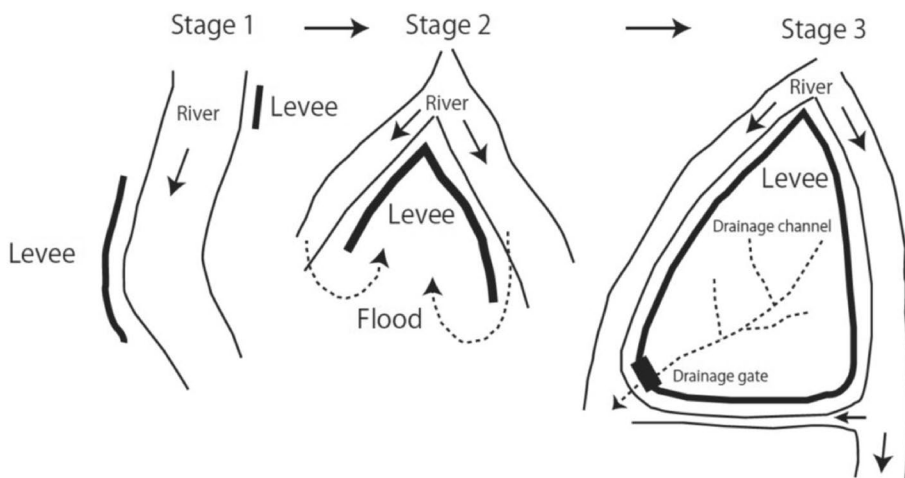
This existing academic research makes the Kabu-ido system an interesting topic. Fortunately, in the case of the Kabu-ido system, written records have been kept. These make it possible to reconstruct in detail both the process of groundwater development and how 200 years ago local people attempted to mitigate the negative side-effects of groundwater development through various restrictions on the use of wells. This paper tells this story as follows: the natural and social background of the Kabu-ido system is described in the second section; the research material (local diaries and public expenditure notes) are presented in the third section; the fourth section reconstructs how the Kabu-ido system operated, and presents the outcome of controlling the number of the wells in one village of the Fukuzuka Ring Levee, Niremata Village; the fifth section considers the factors that influenced the effectiveness of groundwater use control with aid of the commons studies framework; and the sixth section contains the conclusions.

## A Brief History of the Kabu-ido System and its Geographical Background

### Ring Levees: Geographical Background of the Kabu-ido system

The present paper focuses on the Kabu-ido system of the Fukuzuka Ring Levee. A ring levee is a community that is encompassed by a levee for flood protection. This structure sets the geographical conditions for the development of the Kabu-ido system. Thus, it is useful to explain what a ring levee is, including the configuration of a ring levee, in general before explaining the history of the Kabu-ido system.

Figure 1 shows a development model of a ring levee by Ando (1988). According to the model, a ring levee is completed through three stages: a partial levee (stage 1), an inverted U-shaped levee (stage 2) and an enclosed levee (stage 3).



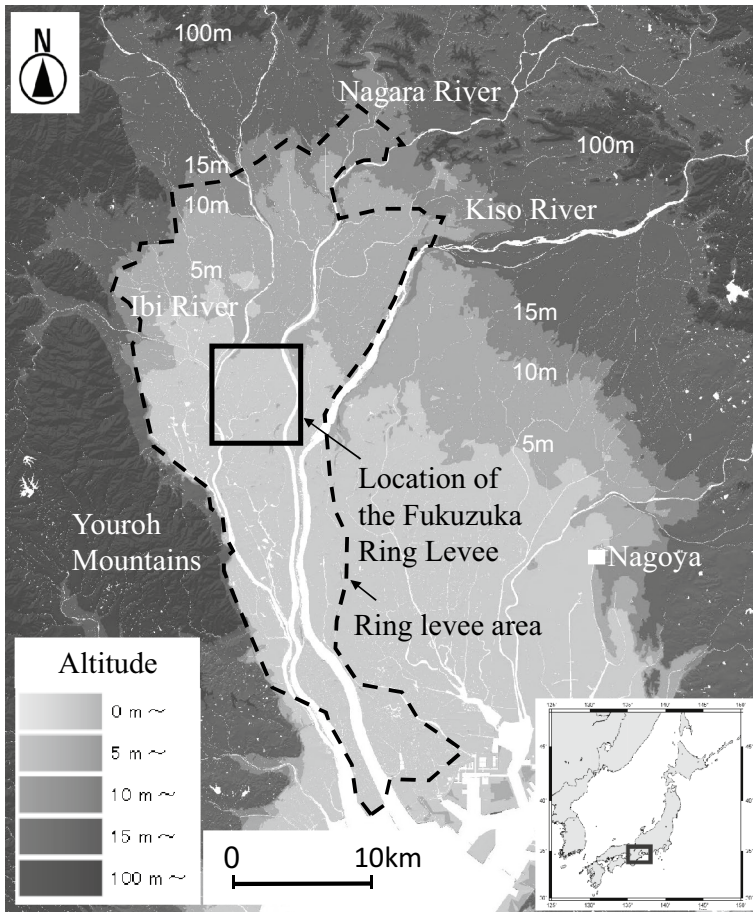
**Fig. 1** A development model of ring levee (Source: (Ando 1988))

The Noubi Plain, where many ring levees were created, suffered from frequent floods owing to the confluence of three big rivers (Ibi, Kiso and Nagara). Although local people constructed levees as a countermeasure, early levees were so short that flood damage could not be prevented (stage 1 in Fig. 1). Repeated overflow delivered debris to make slightly elevated areas near riverbanks. Such areas are called natural levees. Early settlements were formed upon the natural levees, because the slightly higher elevation was convenient to avoid inundation risk. Then, local people gradually connected natural levees to develop an inverted U-shaped levee (stage 2 in Fig. 1). The lower land around a natural levee was used for agriculture or fisheries. The lowest area was left as a marshland. The marsh played a role as a retarding basin in event of a flood. Even if floods reached the agricultural and settlement area from downstream, the force of overflow was decreased compared with a flood directly hitting the area from upstream. Moreover, local people could even take advantage of fertile soil after flood. At the last stage, inverted U-shaped levees were extended to complete an enclosed levee (stage 3 in Fig. 1) or ‘ring levee’. The purpose of enclosing was to change the marshland into agricultural land and protect the newly developed paddy fields from flooding (Ando 1975; Itoh and Aoki 1979).

However, the creation of a ring levee caused a new problem—that of drainage. After heavy rain, water often remained within the levee and such impounded water damaged paddy fields. Drainage channels and gates were constructed to cope with this problem. The former collected excess water inside and delivered it to the latter, which was constructed at the lowest point. The drainage gate opened and shut automatically using changes in the water level of surrounding tidal rivers. When the water level rose owing to high tides, the gate was pushed back and closed. When the water level fell owing to low tides, the gate was opened and released the impounded water. Enclosed levees, drainage channels and drainage gates are the three basic components of a ring levee (Ando 1988). There were more than 80 ring levees in the late nineteenth century on the Noubi Plain, (Bekki 1932). Figure 2 is a map that shows the ring levee area on a contour map of the current Noubi Plain. The study area of this paper (the Fukuzuka Ring Levee) is located in the middle of the ring levee area.

### The Fukuzuka Ring Levee and its water issue

The Fukuzuka Ring Levee was the first community which created the Kabu-ido system. Figure 3 shows an enlarged map of the Fukuzuka Ring Levee in the late nineteenth century. It is a modified map that was originally published in Editorial Committee of Growing Wanouchi (1996). As this figure indicates, the Fukuzuka Ring Levee contains the three basic components (enclosed levee, drainage channel and drainage gate). The drainage channel runs from north to south in the middle of the ring levee. This ring levee is bowl-shaped, sloping downwards from north to south. Early settlements were built on the natural levee to the north. There were ten villages that were called the upper villages. They correspond to the villages in regular text font in Fig. 3. After the 1620s, as the southeastern part began to be reclaimed from wetlands to paddy fields, local people expanded the levees from the northeastern to the southeastern area to protect the newly developed paddy fields from flooding, resulting in a complete ring levee as shown in Fig. 3. The new settlements in the lower areas are referred to as the lower villages. They correspond to the six villages named in italics in the lower part of Fig. 3. The word “shinden” is attached to the end of their names. “Shinden (新田)” is Japanese for “newly developed paddy field”. Nowadays, the name of the Fukuzuka Ring Levee is no longer used. The current name is Wanouchi



**Fig. 2** Map of ring levee area on the Noubi Plain, Japan

Town, Gifu Prefecture. Wanouchi (輪之内) means “inside a ring.” This shows that Fukuzuka was a typical ring levee community (Editorial Committee of a History of Wanouchi Town 1981).

Although the Fukuzuka Ring Levee was surrounded by rivers, such as the Ibi in the west, and the Nagara in the east, local people (especially the upper villages) suffered from an erratic water supply. This issue arose from the dilemma between flood control and water supply: the upper villages had to dismantle a portion of the levee to construct water diversion facilities, which could then become an inlet for floods during periods of heavy rainfall (Okamura 1936). A new drilling technique solved this dilemma. In 1782, a technique for deep well construction with iron bars and bamboo was invented in an adjacent ring levee. It would appear that this technique was quickly adopted by the Fukuzuka Ring Levee farmers. A few local documents record that northeastern villages such as Nishijo, Niremata, Niremata-shinden, and Oyabu began to drill wells right after the technique became available. The wells were artesian and enabled the upper villages to get access to water without dismantling the levee (The Tanahashi Document 1801, 1812; Maruyama 1982). However,



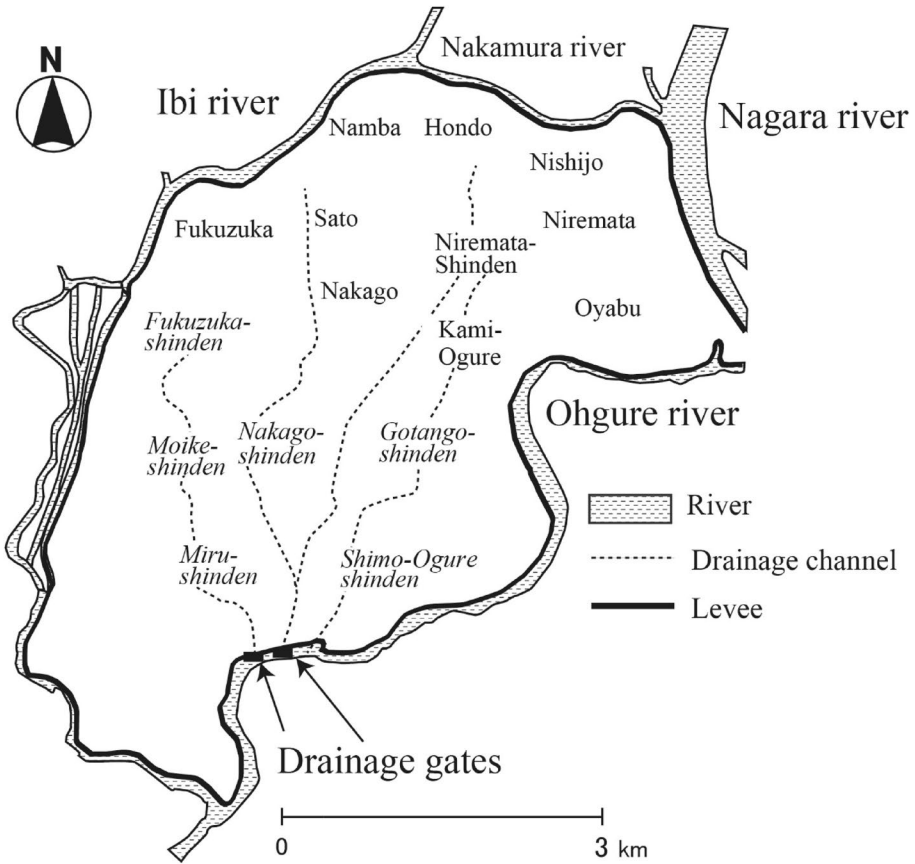


Fig. 3 Map of the Fukuzuka Ring Levee

the lower villages did not welcome this groundwater development. They were worried about impoundment damage to their paddy fields. The Fukuzuka Ring Levee is almost flat and there were no electric pumps at the time. Therefore, it was very difficult for the lower villages to release the drainage water outside the ring levee. (Bekki 1932; Katano 1941; Editorial Committee of a History of Wanouchi Town 1981).

### Creation of the Kabu-ido system

In the summer of 1801, there was very heavy rain and the lower villages found it even more difficult than usual to drain excess water outside the ring levee. The lower villages were worried about the negative impact on rice harvesting and asked the upper villages to shut down wells to decrease the drainage water slightly. However, the upper villages refused to comply with the request. The lower villagers became angry and attacked the houses of well owners in the upper villages. According to the Tanahashi document (1801), approximately 600–700 people from the lower villages poured into the houses of upper village well owners and aggressively demanded the shutdown of wells, taking food, sake, and cigarettes.

This trouble was settled through an apology from the upper villages to the lower ones. A letter of apology from well owners in Niremata Village to the lower villages survives. It says “We are not going to drain water anymore. If you find even a little drainage water from a well, please feel free to set up gates in drainage channel.” (The Tanahashi Document 1801; Editorial Committee of a History of Wanouchi Town 1981).

However, these promises were not kept. In 1811, the lower villages found that water from some wells in the upper villages drained down to their land and the tensions between the upper and lower villages rose again (The Tanahashi Document 1812). To prevent further confrontation, an inter-village agreement regarding artesian wells was reached between the upper and lower villages in 1812 (hereinafter referred to as the 1812 agreement). The agreement consists of 11 articles as mentioned below (Sakurai 1934). The present study has inserted article numbers for reference purposes.

Article 1: The number of artesian wells is confined to 45. No additional wells are permitted. If any upper village breaches this article, all existing wells in that village must be eliminated;

Article 2: Four people (two from the upper and two from the lower villages) act as well operators. A well must be opened in the presence of these operators;

Article 3: The annual salary of a well manager is 1 ryo (unit of money at the time). The upper villages pay this salary;

Article 4: Each well must be locked, and the key deposited with well managers of the upper villages in a key box. The key to the key box is deposited with well managers of the lower villages;

Article 7: A well owner who intentionally lets groundwater flow under the guise of a damaged well must have the well filled in, in the presence of well managers from the lower villages;

Article 8: A well inside a house must be filled in;

Article 9: If an irrigation well does not function adequately, the owner can dig another well in the presence of a well manager from the lower villages;

Article 10: When the drainage gates in the lower villages are closed, wells must not be opened, even in cases of drought;

Article 11: If water flows out from a buried [filled in] well, the well must be completely buried in the presence of well managers of the lower villages. If residents of the lower villages find that upper village residents use the well without reporting its use, the residents of the lower villages should consult the local magistrate’s office.

This agreement was significant in that it set out the institutional foundation for groundwater utilization by introducing a variety of rules, including an upper limit on the number of wells (the details will be explained later). The institutional arrangements in the 1812 agreement were later called the Kabu-ido system.

## Analytical methods

### Diaries

This paper used descriptions from diaries kept by two local families (the Nishimatsu and the Tanahashi families) in the Fukuzuka Ring Levee to investigate the actual operation of the Kabu-ido system. The Nishimatsu and Tanahashi families were wealthy farmers who performed the duties of a *Shouya* (庄屋) (a position that is similar to a village mayor) for



generations in Nishijo and Niremata villages, respectively. Both villages had a strong relationship. They were adjacent to each other, less than 1 km apart, as the early settlers of Nishijo subsequently developed Niremata. (Editorial Committee of a History of Wanouchi Town 1981). Although the Nishimatsu diary was investigated by Narimatsu (2000), the focus was not on groundwater use, but on the daily life and social interaction of the family. Endo (2016) used the diary to explain the operation of the Kabu-ido system, but relied solely on the Nishimatsu diary and used only limited descriptions. The current study not only examined the other descriptions, but also used the Tanahashi diary and other primary sources to expand previous work by showing in further detail how the Kabu-ido system was operated via interactions between the upper and the lower villages.

Diaries are regarded as an important information source for research in various fields including historical studies. Duke (2012) and Alaszewski (2016) pointed out the disadvantages and benefits of using diaries. In terms of disadvantages, their usefulness is limited in that records are often fragmented and show just a small snapshot of information. In addition, the descriptions are subjective. However, diaries have the following advantages. First, they contain records of events that readers cannot easily access through other means, especially when the informants are no longer alive. Second, daily records are likely to be accurate—diaries enable individuals to make records at the time, thus minimizing recall problems.

The volume of the diaries for this study is large enough to compensate for disadvantages of using diaries to some extent. The Nishimatsu diary was written across three generations and it covers 60 years during the period from 1810 to 1884. The Tanahashi diary covers 17 years during the period from 1807 to 1884. I counted the number of days for which the diaries referred to wells at least once in a day. Figure 4 shows the changes in the number of these days. As the figure shows, the Nishimatsu Diary referred to wells more regularly than the Tanahashi Diary through the years. The Tanahashi Diary's descriptions of wells were not frequent, but tended to be intensive especially after late 1850s. Description of wells were found in the two diaries on 537 occasions. Although the descriptions of wells in the diaries were very fragmented, it

Number of days where description of well could be found

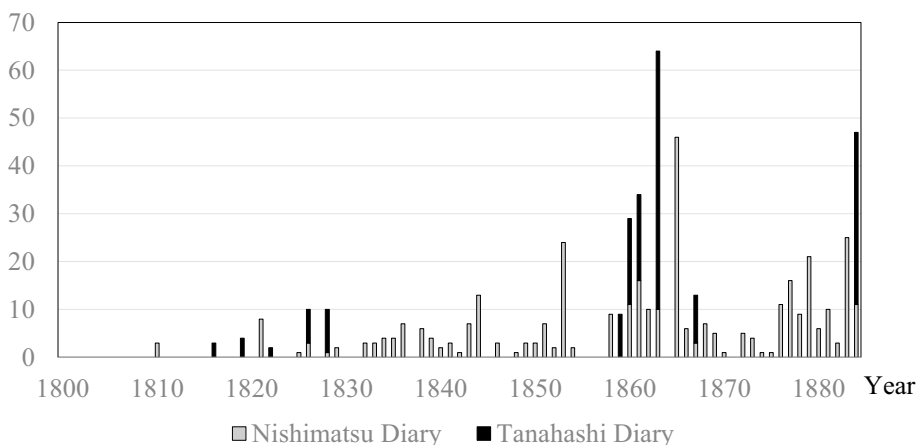


Fig. 4 Changes in number of days with description of well

was possible to reconstruct the operation of the Kabu-ido system by connecting various descriptions of wells in different years with reference to the related articles in the 1812 agreement. Moreover, these diaries have a peculiar advantage in studying the Kabu-ido system because they cover a timespan for which little information about the system is available. The surviving historical documents mainly cover the 1810s, when the Kabu-ido system was created, and the 1870s, when the system was largely modified (Katano 1941). Only very few records that were made between these two periods could be found. Thus, how the Kabu-ido system was operated after its creation has remained unknown.

## Local expenditure notes

The present study also made use of the *Tachiai Wappu Cho* (立会割賦帳) (an annual expenditure note). There were sixteen villages in the Fukuzuka Ring Levee. Each village enjoyed some degree of autonomy. Of these villages, we know that at least Niremata Village recorded public expenditure notes regularly. These cover 24 out of the 66 years between 1812 and 1877; the period from the creation of the Kabu-ido system to its major revision. Descriptions regarding wells were found in 22 out of the 24 years of expenditure notes. For example, the public expenditure note in 1853 provides the following descriptions:

“Silver 9 hun 2 rin To Ubei (person’s name) as land tenure for construction of Kajiya well”

“Silver 3 hun 9 rin To Tomisaburo (person’s name) as ditch tenure for Kanatsubo well”

“Silver 112 monme 3 hun 4 rin Worker fee for provisional well construction”

The left side of the description provides information on money. In the Edo period, there was no single, common currency that prevailed across Japan. The main currency (gold or silver) differed from place to place. Silver was used as the main currency in the Fukuzuka Ring Levee at the time. Monme, hun, and rin were the units. The decimal system was used: 1 monme was equal to 10 hun, and 1 hun was equal to 10 rin (Kato 2000). The right side provides the purpose of the expenditure. “Kajiya” and “Kanatsubo” are names of places. Thus, this expenditure note shows information on the place where a well was drilled as well as the cost of each item. In terms of the aims of this paper, information on place names was very important, because it makes it possible to estimate the minimum number of wells in a year by totaling the numbers.

The upper limit on the number of wells was set at 45 in the 1812 agreement. The well allocation per village is shown in Table 1. The Table indicates that Niremata Village was allocated five wells. Thus, if the number of places in the public expenditure note was less than five in a given year, it means this regulation worked in that year. If, however, the number was more than five, then we can surmise that this regulation did not work. Unauthorized wells might have been drilled secretly, or regulations might have been loosened temporarily. It would certainly be preferable to do this calculation for each village. This was, however, impossible because of a lack of documentation. Thus, this paper had no choice but to limit the analysis to the case of Niremata Village.

**Table 1** Well allocation in the 1812 agreement

| Village name    | Well allocation |
|-----------------|-----------------|
| Fukuzuka        | 9               |
| Hondo           | 1               |
| Kami-Ogure      | 6               |
| Nakago          | 2               |
| Namba           | 4               |
| Niremata        | 5               |
| Niremata-shiden | 4               |
| Nishijo         | 4               |
| Oyabu           | 4               |
| Sato            | 6               |
| Total           | 45              |

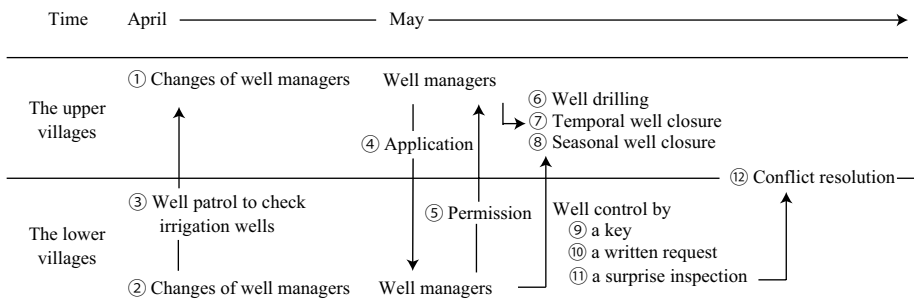
## Results

### Operation of the Kabu-ido system

In this section, the operation of the Kabu-ido system was reconstructed mainly from the descriptions in the 1812 agreement and the local diaries. The annual operation of the Kabu-ido system is summarized in Table 2. The first row shows the timeline. As will be explained later, references to a well often started in April in a year. The second and third rows describe the processes in the upper and lower villages, respectively. The date information in Table 2 and the diaries is based on the traditional lunar calendar, which was used until the early 1870s. Table dates reflect those of the calendar in use at the time of the diary authorship.

The Kabu-ido system was operated through interactions between well managers called *Ido-soudai* (井戸惣代) from the upper and lower villages. Here, “*Ido*” means a well and “*soudai*” a representative. It seems that the upper villages rotated their well managers and the newly-appointed well managers took over from their predecessors in April. The following description can be found in the Nishimatsu Diary (April 16, 1835): “Today, a message came from the lower villages that patrolmen would be sent to Nishijo tomorrow. Toubei and I were appointed as the *Ido-soudai* this year.” The same reference can be applied to the lower villages. Although the information regarding the lower villages is very limited, the

**Table 2** Operation of the Kabu-ido system



names of well managers from the lower villages often changed (Endo 2016) (processes ①, ② in Table 2).

Descriptions of wells often began in April in the Nishimatsu Diary, when a few well managers from the lower villages were documented as visiting the upper villages on well patrols. The oldest description dates back to April 1, 1821. Well patrols also appear in records for the following dates: April 29, 1836; April 14, 1841; and April 17, 1852. Moreover, a description from April 1, 1865 used the phrase “annual well patrol as usual”, which showed that the lower villages carried out well patrols over a long period of time. Furthermore, the lower villages sometimes announced well patrols in advance and the upper villages treated them to food and sake (April 16, 1835 and April 17, 1852). This suggests that a well patrol in April had two purposes: the first was to check irrigation wells in the upper villages before rice transplanting, which usually started in early May. A description on April 29, 1836 implies that patrolmen checked whether there were damaged wells where the flow quantity would be hard to control. The second was to create an occasion for newly-appointed well managers from the upper and lower villages to meet for the first time in a year (process ③ in Table 2).

As mentioned before, unregulated well construction in the upper villages could lead to conflicts with the lower villages by causing impoundment problems for the latter’s paddy fields. Under the Kabu-ido system, to avoid the conflicts, groundwater use by the upper villages was subject to a permit from the lower villages. There are pieces of evidence that show how this was done. One says that well managers from the lower villages were present to see the opening of a well. A description on July 25, 1844 says “It’s fine and cool today. Four well managers from the upper and lower villages were present to see the opening of a well in Imao.” Second, the keys from both the upper and lower villages were necessary for the opening of a well. A description from April 24, 1835 states that “a key for a well was sent for from Tobei’s home.” These show that Articles 2 and 4 of the 1812 agreement were indeed observed (processes ④, ⑤, ⑥, ⑦ in Table 2).

Groundwater use in the upper villages was regulated closely in order not to generate excessive drainage water. A record on May 8, 1860 from the Tanahashi Diary describes how a written request for a temporary closure of wells was circulated among the upper villages, even though rice transplanting had just begun. The reason for the request was a long period of rain at the beginning of the month. From this perspective, the temporary closure can be regarded as the upper villages displaying consideration for the lower villages (processes ⑧, ⑩ in Table 2).

There were a few descriptions for the closure of a well, although little information is available on how long the irrigation season would last each year. An example can be found in the record for June 29, 1841 in the Nishimatsu Diary: “Today, a well at Goemon’s house was closed in the presence of two well managers from the lower villages, Mr. Okuemon of Nakago-shinden and Mr. Magouemon of Moike-shinden.” Another description on December 11, 1853 says “A letter came from well managers of the lower villages. It said they would come with some workers to bury a provisional well tomorrow.” These showed that well managers from the lower villages were present at both the closing and opening of a well as depicted in Articles 7, 9, and 11 of the 1812 agreement (processes ⑨, ⑪, ⑫ in Table 2).

The lower villages carried out surprise inspections as well as inspections with advance notification. A description on March 14, 1865 says “An anonymous letter was sent to Mr. Shinsuke’s house in Nakago-Shinden. Shinsuke and I opened the letter together. It accused that Mr. Dampei in Nishijo Village had secretly drilled an indoor well and warned the well should be shut down.” In this case, those who discovered the rule infringement asked the

well managers to deal with a well that broke the rules. A record from March 3, 1876 in the Nishimatsu Diary also shows that Hikobei, a resident of Sato Village, was caught in the middle of secretly drilling. This showed that secret inspection sometimes caught the rule violator directly (process ⑩ in Table 2).

It seems that well managers in the upper villages acted as liaison with the lower vil- lages to resolve conflicts caused by rule infringement. Two letters, one written in Septem- ber 1827 and one in June 1841, show that conflicts took place between the upper and lower villages. While Niremata Village was accused of overlooking two unauthorized wells in the former case, in the latter case Oyabu and Nishijo Villages were condemned for leaving artesian wells unmanaged, allowing them to overflow. In both cases, the *Shouya* (village mayor) of the accused villages and well managers at the time admitted the fact and sent a letter of apology to the lower villages in their joint names. In particular, in the latter case, the parties from the upper villages promised to set up well patrols within the upper vil- lages to prevent recurrences (The Tanahashi Document 1827, 1841). The 1812 agreement states that if any upper village breaches this article, all existing wells in the village must be eliminated (Article 1). The two documents above imply that such a severe penalty was not implemented immediately (process ⑪ in Table 2).

### Evaluation of the effectiveness of groundwater extraction control

To what extent did this regulation work? Table 3 shows the results of reconstructions of the wells in Niremata Village based mainly on the public expenditure notes. As mentioned previously, the expenditure notes cover 24 of the 66 years from 1812 to 1877, which was the period from the creation of the Kabu-ido system to its major revision. Descriptions of wells appeared in 22 of the 24 years covered. In addition to the expenditure notes, records of a well survey in 1813 (The Tanahashi Document 1813) and the Tanahashi Diary were used as sources of supplementary information. Consequently, Table 3 has data for 26 years,

**Table 3** Reconstruction of well drilling in Niremata Village

| Place                          | Year | 1810s |      |      |      |      | 1820s |      |      |      |      | 1830s |      |      |      | 1840s |      |      |      | 1850s |      |      |      | 1860s |      |      |      | 1870s |
|--------------------------------|------|-------|------|------|------|------|-------|------|------|------|------|-------|------|------|------|-------|------|------|------|-------|------|------|------|-------|------|------|------|-------|
|                                |      | 1813  | 1815 | 1816 | 1817 | 1819 | 1821  | 1823 | 1825 | 1826 | 1827 | 1828  | 1829 | 1837 | 1841 | 1844  | 1845 | 1849 | 1852 | 1853  | 1856 | 1857 | 1861 | 1867  | 1868 | 1869 | 1870 |       |
| Well without place information |      |       |      |      |      |      |       |      |      | ✓    | ✓    |       |      |      |      |       |      |      |      | ✓     | ✓    | ✓    | ✓    |       |      |      |      |       |
| Well with person's name        | ✓    |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     | ✓    | ✓    | ✓    |       |      |      |      |       |
| Doinouchi                      | ✓    |       |      | ✓    | ✓    |      | ✓     | ✓    | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    |       |
| Gotanda                        |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Hachibu-ichi                   |      |       |      |      |      |      |       |      |      |      |      |       |      |      | ✓    | ✓     | ✓    |      |      |       |      |      |      |       |      |      |      |       |
| Hasaha                         |      |       |      |      |      |      |       |      |      |      |      |       |      |      | ✓    | ✓     | ✓    | ✓    | ✓    |       |      | ✓    | ✓    | ✓     |      |      |      |       |
| Hattanda                       |      |       |      |      |      |      |       |      |      |      |      |       | ✓    | ✓    |      | ✓     | ✓    | ✓    |      |       |      |      |      |       |      |      |      |       |
| Hieta                          |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Kaijva                         | ✓    |       | ✓    | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    |       |
| Kanatsubo                      |      |       |      |      |      |      |       |      |      |      |      |       |      |      | ✓    | ✓     | ✓    | ✓    | ✓    |       |      | ✓    | ✓    |       |      |      |      |       |
| Ki-ike                         |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Koya-ta                        |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      |       |      | ✓    |      |       |      |      |      |       |
| Koya-tori                      |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Nambara                        | ✓    |       |      | ✓    | ✓    | ✓    |       |      | ✓    | ✓    |      | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    |       |      |      |      |       |      |      |      |       |
| Ryoudouji-higashi              |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Senmudou                       |      |       |      |      |      | ✓    | ✓     |      |      |      |      |       |      |      |      |       |      |      |      | ✓     | ✓    | ✓    | ✓    |       |      |      |      |       |
| Taba                           |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      | ✓    |       |      |      |      |       |      |      |      |       |
| Tana-ike                       |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      | ✓     |      |      |      |       |      |      |      |       |
| Tanaka                         | ✓    |       |      |      |      | ✓    |       |      |      |      |      |       |      |      | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    |       |
| Tohu-ike                       |      |       |      |      |      |      |       |      |      |      |      |       |      |      |      |       |      |      |      |       |      | ✓    | ✓    |       |      |      | ✓    |       |
| Yokomakura                     |      |       |      |      |      |      |       |      |      |      |      |       |      | ✓    | ✓    | ✓     |      |      |      |       |      |      |      |       |      |      |      |       |
| Yokomichi                      | ✓    | ✓     | ✓    | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    | ✓     | ✓    | ✓    | ✓    |       |
| Number of wells                | 6    | 1     | 1    | 4    | 4    | 5    | 4     | 3    | 3    | 5    | 2    | 4     | 6    | 7    | 5    | 9     | 9    | 9    | 16   | 6     | 10   | 9    | 4    | 0     | 4    | 1    |      |       |
| Upper limit                    | 5    | 5     | 5    | 5    | 5    | 5    | 5     | 5    | 5    | 5    | 5    | 5     | 5    | 5    | 5    | 5     | 5    | 5    | 5    | 5     | 5    | 5    | 5    | 5     | 5    | 5    |      |       |
| Excess                         | 1    |       |      |      |      |      |       |      |      |      |      |       | 1    | 2    |      | 4     | 4    | 4    | 11   | 1     | 5    | 4    |      |       |      |      |      |       |

in two sections. The columns of the upper section show years for which surviving data are available. Data reconstructions were relatively rich for the 1810s and 1820s, but few records remain for the 1830s and for the 1870s. The rows of the upper section provide the names of places where wells were drilled in a given year. Place names were not always clearly entered in the public expenditure notes. Some wells were referred to as, for example, “a provisional well” or “Mr. Ryuji’s well”. Wells without place name information and wells with a person’s name in the upper section correspond to these cases. Check-marks represent the spatial distribution of wells in a given year. For example, the data for 1817 show that wells were set up in four places: Doinouchi, Kajiya, Nambara, and Yokomichi.

The lower section of the table provides a different perspective. It shows the total number of check-marks in a given year and the upper limit depicted in the 1812 agreement (the upper limit for Niremata Village was five). Thus, if the check marks exceed the upper limit, it can be inferred that the regulations did not work perfectly in the given year. The surviving data show that, while regulation worked in 16 out of 26 years (62%), excess wells were drilled in 10 out of 26 years (38%). Thus, it is possible to say that, in Niremata Village, quantitative restrictions worked in some years and did not work in others. Although the survival rate of public expenditure notes differs among the decades, the regulation was comparatively successful in 1810s and 1820s.

## Discussion

### The Kabu-ido system from viewpoints of the commons studies

In this section, factors that influenced the effectiveness of the regulations in Niremata Village are discussed within the analytical framework of the commons studies. A central issue in the commons studies is to search for the elements of an institution that prevent excessive use of common-pool resources. Common-pool resources have two key characteristics: difficulty of exclusion and rivalry in consumption. Difficulty of exclusion implies that controlling a range of beneficiaries through physical or institutional means may be prohibitively expensive. Rivalry in consumption indicates that an individual’s consumption of the resource reduces the potential consumption of others. Natural resources, generally, tend to share these common-pool characteristics and groundwater is a typical example (Dietz et al. 2002; Ostrom et al. 1999). It should be noted that commons studies have focused on the lowering of groundwater tables caused by excessive groundwater development (Blomquist 1992; Ross and Martinez-Santos 2010; Boone and Fragaszy 2018). The background problem of the Kabu-ido system was, however, excessive drainage water from artesian wells. Users within a village were competing for a scarce well permit, and/or possibly better access to the water from a permitted well, rather than for scarce groundwater. Although these problems (lowering of water tables versus excess drainage) appear different at first glance, both involve, in principle, an excessive use of groundwater. Thus, it is possible to apply the analytical framework of the commons studies to the Kabu-ido system.

While nationalization or privatization have been proposed as solutions to the excessive use of common-pool resources, researchers on commons have considered a third solution: collective action by the resource users (Dietz et al. 2002). The commons analytical framework is applicable to the Kabu-ido system because the system was created and operated by local resident themselves. The self-imposed regulation in the Kabu-ido system was done at two levels:



inter-village and intra-village, as will be discussed below. Local residents limited groundwater use through such dual internal surveillance with little recourse to local government at the time.

Generally, an internal settlement called *Naisai* (内済) was the principal resolution for water conflicts in the Edo Period (1603–1867). During this period, even if parties could not resolve a water dispute and filed a lawsuit, the government rarely made a decision (at that time, administrative and judicial powers were not clearly separated). Instead, it promoted an internal settlement by further negotiations between the parties involved. A civil mediator was appointed by the government, if necessary. As a water dispute is affected by changing factors such as rainfall and actual water use, local water users have much more information on local conditions than government officials. The government at the time was afraid of losing its authority by making a decision that did not fit with local circumstances. Thus, internal resolution was strongly recommended as a practical method in cases of water disputes (Kobayakawa 1957; Maki 1942; Ohira 2013; Otake 1952).

The Kabu-ido system was no exception to this rule. In this case, the local government appointed *Shouya* from adjacent ring levees as mediators to promote an internal settlement. The 1812 agreement, which underlay the Kabu-ido system, expressed the result of the settlement in words. Moreover, in cases where various restrictions on groundwater use by the agreement were breached, upper and lower villages negotiated via well managers to prevent an escalation of the conflict, as the Nishimatsu and Tanahashi Diaries described. The characteristics of the Kabu-ido system reflected the general policy of judicial decision-making at the time, in this case for a common resource.

Ostrom's design principles offers a representative framework to consider conditions when a collective action by resource users works (Ostrom 1990; Cox 2010). The principles comprise the following eight conditions: clearly defined boundaries, congruence between appropriation and provision rule and local conditions, collective-choice arrangement, monitoring, graduated sanctions, conflict resolution mechanism, minimum recognition of rights to organize, and nested enterprise. Table 4 summarizes how the Kabu-ido system corresponds to Ostrom's design principles.

According to Ostrom (1990), the core problem of common-pool resource management is how the resource users undertake monitoring and sanctioning by themselves rather than through external authorities. This was also a core problem for the Kabu-ido system. Monitoring and sanctioning unauthorized wells were communal benefits for the lower villages in that they decreased overall drainage damage. However, in such a situation, each village had an incentive to be a free-rider because each village could enjoy the benefits without making a contribution, as long as the other villages conducted monitoring and sanctioning. If such free-riding prevailed in the lower villages, the paradoxical situation would arise in which no village cooperated to realize its common benefit. If the benefit from monitoring of unauthorized wells (the avoidance of excessive drainage water) is assumed to be constant for the simplicity of analysis, the solution to the free-rider problem depends on monitoring costs. If the benefits outweigh the costs, it is reasonable to assume that more detection would have been undertaken and that the 1812 agreement would have been more likely to have been observed. If the benefits are small in comparison with the costs, then the motivation to impose regulations would probably decrease and many unauthorized wells would be likely to have been drilled.

**Table 4** Ostrom's design principles and their application to the Kabu-ido system

| Design principles   | Description  | Application to the Kabu-ido system  |
|---|--|---|
| 1 Clearly defined boundaries  | Those who have rights to use the resource are clearly defined, as are the boundaries of the natural resource system  | The upper limit on the number of wells was set and well allocation per village was clearly agreed. In addition, Fukuzuka Ring Levee was surrounded by rivers and separated from adjacent communities completely |
| 2 Congruence between appropriation and provision rule and local conditions      | Appropriation rules restricting time, place, technology, and/or quantity of resource units are related to local conditions                                   | Restrictions on groundwater use reflect differences in elevation between villages and the difficulty of releasing the drainage water outside the ring levee   |
| 3 Collective-choice arrangement   | Most individuals affected by the operational rules can participate in modifying the operational rules  | The basic rule of the Kabu-ido system (the 1812 agreement) was a product of negotiation between the upper and lower villages  |
| 4 Monitoring  | Monitors are present and actively audit CPR conditions and appropriator behavior   | Well inspection is conducted with or without advance notifications  |
| 5 Graduated sanctions   | Appropriators who violate operational rules are likely to be assessed for graduated sanctions  | Sanctions range from a letter of apology to elimination of all the existing wells   |
| 6 Conflict resolution mechanism   | Appropriators and their officials have rapid access to low-cost local arenas to resolve conflicts among appropriators or between appropriators and officials | Well managers in the upper villages acted as liaison with the lower villages to resolve conflicts caused by rule infringement   |
| 7 Minimum recognition of rights to organize                                     | The rights of appropriators to devise their own institutions are not challenged by external governmental authorities   | The Kabu-ido system reflected the general policy of judicial decision-making at the time of Naisai (internal settlement)  |
| 8 (For common-pool resources that are parts of larger system) nested enterprise | Appropriation, provision, monitoring, enforcement, conflict resolution, and governance activities are organized in multiple layers of nested enterprises     | Groundwater use was limited through two-level surveillances (inter-village and intra-village surveillance)  |

## Factors that lowered monitoring costs

This paper attempted to analyze the factors that might have influenced the monitoring costs by referring to the 1812 agreement and to the descriptions in the Nishimatsu Diary. The diary documents actual well management operations in Nishijo Village. It is reasonable to assume that the diary content can also be applied to Niremata Village, because these villages were adjacent to each other and were separated by less than 1 km.

The 1812 agreement contained mechanisms for the lowering of monitoring costs. First, it can be assumed that well management with keys led to cost reductions (Article 4). The upper villages could not open a well without a key held by the lower villages. Because of this arrangement, the lower villages did not need to monitor all the time.

Second, it can be inferred that rules of joint responsibility (Article 1) not only made the penalty system practical, but also provided the upper villages with an incentive to check for illegal users. Such an arrangement enabled the lower villages to transfer a part of the monitoring activities to the upper villages. Each village in the upper area could have been a free-rider in the activities. This problem was mitigated, however, by clarifying who was responsible for well management: the well managers. Leaving the monitoring activities only to the upper villages would not have worked. Consequently, the lower villages conducted their own secret inspections, thereby putting pressure on the upper villages to carry out internal inspections. A description in the Nishimatsu Diary (May 8, 1860) states “A letter came from well managers: Mr. Jinzaburo of Sato Village and Mr. Goro of Niremata Village. In the letter, they warned that the well should be closed temporarily because the lower village tended to be concerned about drainage water in this season. In addition, the letter mentioned a rumor that secret well-inspectors were being sent to the upper villages.” This diary entry demonstrates the dual surveillance system very clearly.

Finally, the monitoring cost was reduced by the prohibition of an indoor well (Article 8). It is certainly much more difficult to check an indoor well compared to an outdoor one. It seems that the effect of this arrangement appeared in Table 3. The frequency of check marks indicates that wells were mainly drilled at Kajiya, Dinouchi, Nambara, Tanaka, and Yokomichi. The Kajiya and Doinouchi wells appeared 21 times in 26 years, which equates to a high appearance ratio of 81%. It is probable that wells with a high appearance ratio were outdoor ones. This inference is based on a well survey conducted in 1813, the year after the 1812 agreement was made (The Tanahashi Document 1813). The survey reported that wells at Tanaka, Kiyoshichi, and Hanzaemon had been replaced by Kajiya, Doinouchi, Yokomichi, Tanaka, and Nambara. Kiyoshichi and Hanzaemon were male names, and thus the wells were assumed to be indoor wells; that is, wells built in their houses. Kajiya, Doinouchi, Yokomichi, Tanaka, and Nambara were, however, place names, and thus probably referred to outdoor wells. It can be inferred that this change arose from Article 8 of the 1812 agreement, which prohibited indoor wells. Moreover, there were five names in total (Kajiya, Doinouchi, Yokomichi, Tanaka, and Nambara). Thus, it seems reasonable to contend that these five wells correspond to the wells allocated to Niremata Village in the 1812 agreement (see Table 1). We have, however, no definite information to explain why the well at Takana was closed down and replaced, but subsequently was permitted to re-open.

## Factors that increased monitoring costs

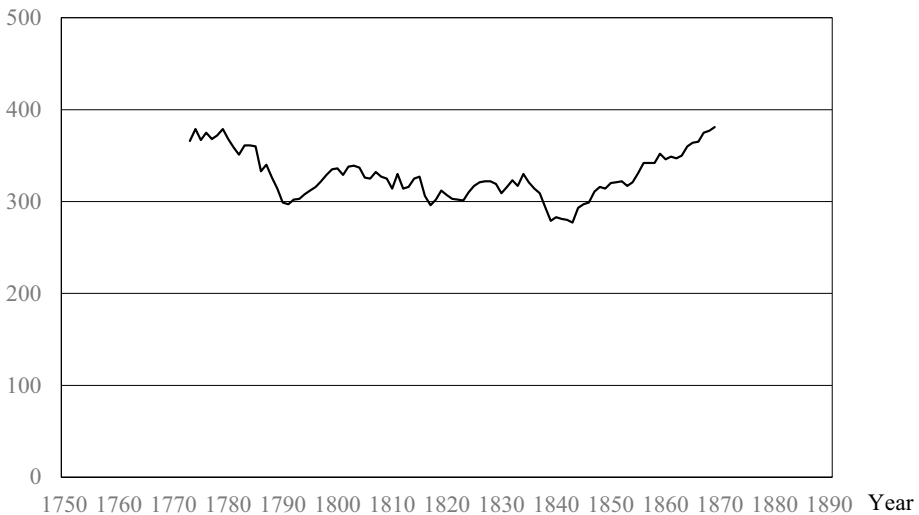
The physical characteristics of groundwater can lead to higher monitoring costs than for surface water. While surface water is diverted by visible infrastructures, including head-water gates, ditches, and ponds, artesian groundwater can be extracted by much smaller and simpler infrastructure. This could have enabled the upper village to set up indoor wells that would be difficult to detect. Furthermore, groundwater is invisible and occupies a wide area. Because electric power was not available at the time, the local people had no choice but to move surface water through differences of elevation. This restricted the selection of water diversion points. However, such restrictions were reduced after techniques for deep well construction reached the upper villages. Artesian wells enabled the local people to select water extraction points in a more flexible manner. As a result, such points were spread over a wide area, which increased the monitoring costs.

Monitoring costs were also affected by climatic conditions. The Fukuzuka Ring Levee experienced floods as well as droughts. Prolonged drought caused water deficits, which increased the groundwater demand. Table 3 shows a high number of wells for 1853. There is no doubt that the summer of 1853 was extremely hot and dry. Evidence for this is provided by the fact that a new ditch was constructed in this year. The construction petition submitted to the local government had the following description: “The drought in this summer is so rare that there have been no examples in recent years.... We made some provisional wells but its water supply is not enough due to prolong hot days.” (The Nishimatsu Document 1853). Moreover, the Nishimatsu Diary entry for June 28, 1852 describes how a ritual rain dance had taken place. Although such rituals might be held every year, the reference to the ritual in the Nishimatsu Diary is highly unusual. Thus, it seems probably that drought continued for two successive years. The diary in 1853 also repeated words such as “hot,” “sunny,” and “dry” from June to August.

The climate conditions prompted local people to establish more wells than usual. While these deductions can certainly be applied to the case of 1853, information on other years is very limited. Thus, it is impossible to say that the existence of unauthorized wells in other years can be attributed to drought. Such an assessment requires a long-term reconstruction of climate conditions, which is beyond the scope of this paper. Table 3 shows that the number of unauthorized wells increased after the 1840s. Although this suggests that the spirit of compliance faded with successive generations, historical documents do not provide enough information to justify this premise.

Finally, this paper considered whether population change affected changes in the number of wells by increasing water demand. This is not likely to be the case here. Figure 5 shows the population change in Nishijo Village based on Hayami (1992), which reconstructed demographic data by using surviving family registers of each household of the village. These records were also kept by the Nishimatsu family. The data cover from 1773 to 1869 and overlap the timespan when the Kabu-ido system was operational. As Fig. 5 shows, during the period, the population changes were limited to approximately 100 people. Unfortunately, it is impossible to reconstruct the population for whole upper villages because similar documents did not survive in other villages. However, it is unlikely that the population increased drastically in other villages because each village was adjacent in a narrow spatial area and the living conditions were similar. Therefore, it can be assumed that, even if demographic change might affect water demand and the number of wells, the effect was very limited.

## Population in Nishijo Village



**Fig. 5** Population change in Nishijo Village, 1773–1869

### Flexibility in the numerical regulation of allocated wells

The 1812 agreement allocated five wells to Niremata Village. It is interesting to consider how rigid this numerical regulation was: were wells that exceeded the limits immediately identified as unauthorized wells, or was there some flexibility in the implementation of the numerical regulation that would have enabled the lower villages to temporarily allow wells beyond the limits in the event of drought? The following points suggest that the latter was the case. The flexibility indicates that there were three kinds of wells: legal, temporary, and illegal.

First, the Nishimatsu Diary mentions “provisional wells” in years of drought. For example, a record on June 27, 1853 in the Nishimatsu Diary states that “a request to establish provisional wells was made to the lower village well managers,” and a few days later the diary describes how “drilling provisional wells began today. The lower village well managers were present as observers.” This shows that the wells were drilled with the permission of the well managers. On December 10, 1853, the lower villages sent a letter to the upper villages, saying “We will visit the upper villages tomorrow with workers to bury the provisional wells.” A similar record appears in the diary on August 11, 1876, which was also an extremely dry year; the upper villages applied to the lower villages for permission to drill provisional wells as they did in 1853. Table 3 suggests that local people usually drilled wells at Kajiya, Dinouchi, Nambara, Tanaka, and Yokomichi in Niremata Village. However, in 1853, they also drilled in places that were not specified before, such as Hieta and Ryoujouji-higashi. It can be inferred that these wells corresponded to what the Nishimatsu Diary calls “provisional wells.” This implies that the upper limit of the 1812 agreement was relaxed to adjust to climatic conditions.

Second, there was a variation in water demand among the lower villages. Generally, although the lower villages tended to suffer from impounding damage, some of the lower villages faced water deficits in times of drought. This observation is based on the fact that

lower villages such as Gotango-shinden, Nakago-shinden, and Shimo-ogure-shinden were entitled to use the surplus water from a ditch constructed in 1853. This implies that these villages shared a common interest with the upper villages in drilling wells in periods of drought, because drainage water from the artesian wells in the upper villages could be a valuable water supply for the relevant lower villages. It seems reasonable to assume that such water demand in the lower villages allowed for flexibility in the numerical regulation of allocated wells only in times of extreme drought. This is supported by the fact that well patrols by well managers continued for a long time and surprise well inspections were often conducted in normal years. Thus, it can be inferred that the rigidity of the numerical regulation on the number of wells changed in accordance with the circumstances.

## Conclusions

This paper discussed the Kabu-ido system, which used to exist in the Fukuzuka Ring Levee on the Noubi Plain, Japan. The system was a set of rules, including regulation of the number of wells per village, introduced to de-escalate water conflicts caused by excessive groundwater development. It was operated in a manner in that the rules were enforced not by an external authority, but the community residents themselves. While previous work has addressed the evolution of this institution, little is known about its daily operation and the effectiveness of its regulation of the number of wells. This paper reconstructed the daily operations by principally referring to local diaries (the Nishimatsu and Tanahashi Diaries) and revealed how the wells were controlled by the well managers. Additionally, the effectiveness of the numerical regulations was evaluated by comparing the allocations given in the 1812 agreement with the actual number of wells listed in village expenditure notes. The comparison indicated that, for Niremata Village, the self-imposed regulations did not always work. The analytical framework of the commons studies showed that the cost of monitoring unauthorized wells was a crucial factor in whether such regulation worked or not. While the 1812 agreement included provisions that lowered the costs of monitoring for unauthorized wells (well management with keys, rules of joint responsibility and the prohibition of indoor wells), the natural characteristics of groundwater and climate increased these costs. This study suggests that it was highly likely that the numerical regulation was temporarily loosened according to climatic conditions.

In future research, the Kabu-ido system should be compared with other case studies. For example, there were customary rules for drainage regulation in polder areas in the Netherlands. The geographical conditions of this area are very similar to those of the Noubi Plain. In the early twelfth century, local people encircled their communities with successive levees and formed an organization called the “Waterboard” to deal with flood and drainage problems. The invention of a water-lifting windmill in the fifteenth century made it possible to pump excessive water out of their farmlands more efficiently. However, this sometimes caused a conflict. The windmills in higher areas lifted water above the capacity of a drainage channel and increased the water level, which exposed the lower area to an inundation risk. To solve this conflict, a water-level rule was introduced. If the water level reached the critical point at the indicative windmill, all windmills had to be stopped until the water level dropped again. This rule was introduced owing to the limited storage and discharge capacity of the common outlet system (Dolfing and Snellen 1999; Kaijser 2002). Investigating how such local rules were enforced and comparing them with the Kabu-ido system would enrich historical knowledge of customary water management.



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**Author contributions** Takahiro Endo: Conceptualization; data curation; formal analysis; funding acquisition; investigation; methodology; validation; writing-original draft, review, and editing. Takahiro Endo is a professor of environmental policy at Osaka Metropolitan University, Osaka, Japan. Originally trained as a political science researcher, his research focuses on water policy, in particular groundwater governance, water marketing and water supply in emergency. His work has concentrated on Japan and the State of California, USA.

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## Declarations

**Conflict of interest** The author declares no conflict of interest.

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