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# Water Scarcity and the Sustainability of a Common Pool Resource Institution in the Urban Andes

**Amber Wutich**



**Abstract** The Cochabamba Water War of 2000 was precipitated by Bolivians' defense of common-pool water resources and institutions against privatization. This article examines the design of a water institution and its sustainability during periods of water scarcity in urban Cochabamba. Based on data collected via participant-observation and panel surveys conducted in 72 randomly selected households, I draw three main conclusions. First, the institution operated according to principles found in sustainable resource management institutions in the rural Andes (Trawick 2001) and across cultures (Ostrom 1990). Second, while the function of the common-pool resource institution was stable over the five study periods, the social structures that supported collective choice and operational rules were sensitive to external events including seasonal water scarcity. Third, while institutions with strong historical precedents for contingencies under resource stress may be sustainable, other forms of social organization on which the institution depends may be more vulnerable to water scarcity.

**Keywords** Urban · Water scarcity · Seasonal · Climate · Institutions · Commons · Cochabamba · Bolivia

## Introduction

The Cochabamba Water War of 2000 was actually a series of protests against the privatization of water resources and their management in the department of Cochabamba, Bolivia. After 2 months the protesters were able to secure the nullification of the privatization deal and a return to public control. The protests have come to be considered a moral triumph of impoverished Bolivians over a transnational consortium of private companies (Assies 2003, Olivera 2003). In the initial media coverage, the cause of the Water War was often attributed to Cochabambans' anticapitalist or antineoliberal political activism. More recently, it has been suggested that the reason the protests began was that the first waves of protesters—peasants and urban migrants—rose up to defend common pool resources and institutions (Perreault 2006, Bakker 2007). Much of this argument has been focused on rural communities, as we know little about how common pool water resource institutions function in urban Cochabamba. We do know that water is extremely scarce in the southern region of Cochabamba occupied by urban migrants—a condition that may make urban common pool water institutions unsustainable. I here explore first, how the institutional rules for water distribution work and second, how sustainable those rules are in the face of water scarcity and other stressors in a Cochabamban squatter settlement. Specifically, I examine three questions: (1) How does a common pool water resource function in urban Cochabamba? (2) Are its rules sustainable during periods of severe water scarcity? and (3) Are the underlying institutions (including those for collective choice rules and operational rules) also sustainable during periods of severe water scarcity?

A. Wutich (✉)
School of Human Evolution and Social Change,
Arizona State University,
PO Box 872402, Tempe, AZ 85287-2402, USA
e-mail: amber.wutich@asu.edu

## Sustainability and Vulnerability in Common Pool Resource (CPR) Institutions

Institutions, or the rules and norms that govern human behavior, are crucial for the coordinated exploitation and

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preservation of common pool resources (Crawford and Ostrom 1995). Research on long-enduring commons governance indicates that there are a handful of characteristics shared by sustainable institutions. These “design principles” for institutional success were initially identified by Ostrom (1990) and have been refined in subsequent work (Ostrom *et al*. 1994, Ostrom 2005). To begin, resource users must have the authority to organize themselves independently and to control their common pool resources. This is the right that Cochabambans fought to defend in the Water War. Once the right to organize and control resources is secured, there must also be clearly defined boundaries for the resource system and its beneficiaries. This is particularly important in urban areas, where settlements are contiguous and may not be separated by natural barriers. If the resource system is large or complex, as is often the case in cities, there should be nested levels of oversight to ensure that CPR governance articulates with the rules at all levels. Because following the rules may not be in everyone’s self-interest, there must be monitoring to ensure that all resource users are in compliance with the rules. There should also be graduated sanctioning of people who do not follow the rules; this creates an incentive structure to counteract self-interested rule-breaking. If the rules or sanctions are contested, there must be conflict–resolution mechanisms in place to resolve disagreements. In the case that the rules are no longer working properly, there should be collective choice arrangements so that resource users can modify the institutional rules. Such modifications should ensure that the rules can be adjusted so that the institution maintains a proper balance, first, between resource exploitation and local conditions and, second, between the costs and benefits apportioned to resource users.

While these design principles appear to be necessary for the long-term success of CPR institutions across cultures, they are implemented in culturally appropriate ways in distinct ethnographic contexts. In the Andes, Trawick (2003, 2002, 2001) documented the evolution and sustainability of principles for institutions governing irrigation systems. He identified a set of six basic principles of an irrigation institution in the rural Peruvian community of Huaynacotas, and suggested that these principles may be connected to pre-Incan forms of social organization and shared broadly across the Andes:

1. Autonomy—the community must own and control its water resources.
2. Uniformity—everyone should receive water with the same frequency.
3. Proportionality—people should only take the amount of water that their land entitles them to and that their contributions to the system should be in proportion to their use of it.
4. Contiguity—a strict system of turn-taking is followed in which people are allotted water based on their physical location in the canal system.
5. Transparency—ensures that water is distributed publicly and every community member has the opportunity (and responsibility) to monitor and sanction everyone else.
6. Regularity—governs how the CPR institution responds to conditions of abnormal scarcity.

The regularity principle dictates that no changes are made to the uniformity, contiguity, or proportionality of the system. When shortages do occur, they must be absorbed equally by all households. This is crucial for the long-term sustainability of the institution because it essentially prioritizes the preservation of the system over the well-being of individual households; while individual households may become vulnerable to water scarcity, the system should not.

There is a high degree of overlap between the principles proposed by Ostrom and those observed by Trawick; this reaffirms Trawick’s argument that the Huaynacotas irrigation system exemplifies long-enduring Andean institutions for water management. In reading his work, I was struck by how closely the autonomy, uniformity, contiguity, and transparency principles that Trawick documented were followed in Cochabamba’s squatter settlements. Even the proportionality principle seemed to be followed in spirit, since equity and fairness were key features in these community-run urban water systems. This was surprising because Trawick noted that these principles had become rare even in socially isolated indigenous Andean farming communities (2001), and the principles have never been studied in the context of an urban Andean water system (Trawick, personal communication).

The regularity principle, however, appeared to be nearly impossible to adopt in an urban setting because urban water use is generally reserved for household reproduction, not productive activities. In the case that resource users are operating at or below subsistence level, it would be extraordinarily difficult for community members to adopt and enforce rules that provide people less of a resource than they need to survive. In fact, it is in precisely these situations that rebellions and other forms of violent opposition have emerged (e.g., Scott 1976, Popkin 1979). To counteract such threats, people are likely to adopt flexible social norms and tolerance of self-interested rule-breaking *if* they know that their resource system is vulnerable to periods of severe scarcity (Laughlin and Brady 1978). This theory underlies our understanding of human responses to subsistence threats related to drought and famine and has been validated by a number of case studies (e.g., Turnbull 1972, Laughlin 1974, Colson 1979, Cashdan 1985) and reviews (e.g., Dirks 1980, Corbett 1988, Walker 1989). The regularity rule would directly contradict this because it would force people to share shortages even when they lacked water for basic subsistence needs. Thus, I was interested in understanding whether the regularity rule, which was so crucial to the sustainability of common pool water institutions in the rural Andes, could also be observed in an urban Andean setting.

This is a particularly important question because it sheds light on the sustainability of urban CPR institutions in the face of impending global climate change. Global climate change is expected to make water scarcer in water-stressed areas and increase climatic variability around the world (UNDP 2006). Existing water management institutions may be vulnerable to challenges posed by increasingly unpredictable weather patterns and severe water scarcity (UNDP 2006), particularly in urban areas (Muller 2007). If so, current studies on the institutional impacts of intra-annual climatic variability may shed light on the characteristics that will make CPR institutions sustainable under future conditions of inter-annual climatic variability. Therefore, I examine here how an urban Andean common pool water resource institution performs in the face of threats related to seasonal variability in water scarcity, focusing on Cochabamba, an Andean city that faces serious hydrological and political challenges.

## Water Provision and Scarcity in the City of Cochabamba

The Valley of Cochabamba is located in the eastern Bolivian Andes, and contains a number of alluvial fans, a spring zone, confined aquifers, two rivers, a lake, and a playa zone (Stimson *et al*. 2001). The city of Cochabamba spans the valley floor and is bisected by the Rocha River, which once supplied water to the city's agricultural population. Today, municipal water is supplied by SEMAPA, Cochabamba's public water company. SEMAPA acquires water supplied by well-fields located in the alluvial fan system to the northwest of the valley (Stimson *et al*. 2001), and by reservoirs located outside the valley. Surface water sources located outside the valley provide 40% of Cochabamba's water, while 30 wells provide the remaining supply (SEMAPA 2006). In 2000, control briefly passed from SEMAPA to Aguas del Tunari, the transnational consortium whose actions precipitated the Water War (Assies 2003). Although the return of the water system to municipal control has been widely celebrated, few in the academic community have addressed implications this has for those whose disenfranchisement drove Cochabamba's planners to seek outside funding and management in the first place (Nickson and Vargas 2002). Despite SEMAPA's efforts to improve the existing water system, industrial and domestic pollution have seriously degraded the surface water resources, and over-abstraction and pollution now threaten the aquifer system (Stimson *et al*. 2001, Ledo García 2002,Terhorst 2003).

Beyond these hydrological and technical problems, Cochabamba's municipal water system has another serious problem—inequity. As national economic crises pushed Bolivians into cities to find work, squatter settlements have filled in the water-poor south side of Cochabamba (Assies 2003). Rural migrants and downwardly mobile urbanites have bought up the land, and are now working to legalize their claims to occupy squatter settlements in Cochabamba's impoverished southern districts (Chritéle and Delgado 2007) where even legally recognized communities and land claims have historically not entitled residents to municipal services such as water (CEDIB 2007). In 2004, SEMAPA's service area was enlarged to include southern Cochabamba, but large-scale expansion of the physical water delivery system is not yet financially feasible (Los Tiempos 2004). As a result, municipal water and sewage service is still not available to the majority of residents of Cochabamba's south side (CEDIB 2007).

SEMAPA services are available to approximately 60% of Cochabamba's one million residents (García *et al*. 2003). About 80% of Cochabamba's water supply goes to the north and central zones of the city where the wealthiest residents live (Terhorst 2003). Water provision in Cochabamba's wealthiest households runs up to 165 l per person per day, and water costs less than 1% of household income (Ledo García 2005). In contrast, about 40% of residences are located in the south side of Cochabamba (García *et al*. 2003), which is not covered by the water system, and where 93% of the population is considered poor by Inter-American Development Bank standards (Terhorst 2003). Here, Cochabamba's poorest households use less than 20 l per person per day, and water costs more than 10% of household income (Ledo García 2005). Households that lack access to the municipal water system must find alternative sources of water for daily use, including community water systems, private water vendors, surface water, and rainwater collection.

Among the urban poor, community-based water systems are often considered the best alternative to municipal service. In 120 south-side neighborhoods, Water Committees (*Juntas de Agua*) are responsible for securing water access for local residents (Los Tiempos 2004). While many Water Committees have succeeded in erecting some water infrastructure, not all households can rely on water supplied by community-based systems. In south Cochabamba neighborhoods ranging from relatively new squatter settlements to very established ones, I found that most local water sources provided an insufficient amount of water for daily household needs. In some of Cochabamba's squatter settlements, water sources have disappeared permanently, dry out seasonally, are contaminated, or lack the water needed to support growing populations. Of course, the stressors on south-side water systems—including rapid population growth, desertification, drought, and the possibility of climate change—are only worsening over time, which does not bode well for the future. In this paper, I focus on the sustainability of a community water system in squatter settlement known as Villa Israel.

## Methods

I conducted field research, with the assistance of four Bolivian colleagues, in Villa Israel between June 2003 and July 2005, with a follow-up visit in 2008. A detailed description of the research methods, including the sampling frame and complete interview protocols, can be found in Wutich 2006:53–78. The data collection proceeded in two stages, preliminary research and survey research. During the first stage, I conducted participant observation during the dry season of 2003 and the wet season of 2004. This involved living in Villa Israel, observing daily water distribution at the tapstands, volunteering in community labor projects, and attending community meetings. I learned the strategies that allow people to subsist under water-scarce conditions, including how to acquire water at the tapstand, collect rainwater, and wash clothes in the creek. Conducting participant observation at the height of the wet and dry seasons enabled me to participate in community life when water was relatively abundant and extremely scarce. Building on the results of the participant observation, my colleagues and I spent 2 months conducting in-depth interviews with key informants in which we explored our preliminary observations, developed ethnographic survey protocols, and pretested those protocols.

During the second stage, we conducted a panel study of randomly selected households. We drew a random sample of 96 households based on the community map, which contained 415 residential constructions. Of the 96 households we contacted, 72 households (75%) participated in the survey. The interview protocol included questions about water insecurity, homeownership, tapstand use, participation in community governance, social relationships, and related topics (see Appendix for excerpt). We conducted interviews over a 10-month period that spanned the 2004 wet season, 2004 dry season, and the 2005 wet season. Interviews were conducted at 2-month intervals, making a total of five interviews conducted over 10 months in each household. In each household, we interviewed the person who was most knowledgeable about resource acquisition and distribution (e.g., income, assets, division of labor, acquisition and allocation of water/food). During initial household visits, in which we obtained participant consent and scheduled interviews, we attempted to determine which household member was most knowledgeable about resource acquisition and distribution. In 33% of households, we were unable to determine who was most knowledgeable during the initial visits. In these households, we included all candidates in the study (2–4 people per household). After the fifth round of interviews was complete, we examined the data to determine which household member's answers had the most breadth and depth on questions about resource acquisition and distribution; this respondent was chosen to represent the household in the data analysis. Interviews were conducted in Spanish, Quechua, or Aymara by a fluent speaker of that language. Interviews took an average of 65 min to complete.

The analyses presented here are based on data collected during participant observation and interviews conducted as part of the panel study of 72 households in Villa Israel. To determine how institutional rules govern the distribution of common pool water resources in Villa Israel, I took extensive notes during participant observation and open-ended interviews with survey respondents. I analyzed the notes at intervals during the field research, and asked follow-up questions to develop an in-depth understanding of how the water system functioned. To determine how seasonality affected Villa Israel households, I conducted a repeated-measures ANOVA analysis to test if scores on a 9-point Guttman scale of water scarcity (Hadley and Wutich 2009) differed over the wet-to-dry season cycle. To determine how sustainable the system's rules were during periods of severe water scarcity, I present statistics describing the percent of legitimate beneficiaries and free riders who accessed the community water system over the wet-to-dry season cycle. To determine how sustainable the collective choice rules were during periods of severe water scarcity, I present statistics describing the percent of legitimate beneficiaries and free riders who participated in meetings of the local government over the wet-to-dry season cycle. Finally, to determine how sustainable the operational rules were during periods of severe water scarcity, I conducted a *t*-test, repeated-measures ANOVA, and split-plot repeated-measures ANOVA to determine if the size of community members' and non-community members' social networks—and thus social influence and ability to enforce or break operational rules—differed over the wet-to-dry season cycle.

In 2008, I made follow-up visits to participants in the original study and to the president of Villa Israel's Water Committee. During these visits, I asked a series of semi-structured questions to clarify my interpretation of the completed data analysis and to verify that the community system was still functioning based on the principles I had identified during the 2004–2005 field research. The results presented here include insights gleaned during these visits.

## Villa Israel, Cochabamba

Villa Israel is one of the newer squatter settlements in Cochabamba, located in the foothills at the far southern tip of the city. Like many of Cochabamba's squatter settlements, Villa Israel was established after a *loteador* (land speculator) purchased land reserved for an agricultural greenbelt, illegally subdivided the land for urban settlement, and sold small plots to urban migrants (Goldstein 2004: 76–78). Those who purchased the land are considered lawful landowners within Villa Israel, although few have completed the long process required to legalize land claims at the municipal level (cf. Chritéle and Delgado 2007). The initial settlers were mainly Quechua-speaking highlanders who migrated to Cochabamba after the mining industry collapse of the mid-1980s. Later settlers included urbanites from the cities of La Paz and Cochabamba, ex-coca farmers from Cochabamba's tropical Chapare region, and residents of rural settlements in the highland departments of Potosi, Oruro, and La Paz. The community is now a Bolivian melting pot; it contains a mix of Spanish, Quechua, and Aymara speakers as well as members of Evangelical and Catholic faiths.

Like many inhabitants of Latin American squatter settlements, Villa Israel residents suffer from the economic insecurities associated with low-income employment in the informal sector. Nearly 90% of Villa Israel household heads work in informal sector jobs such as day laborers, domestic employees, market vendors, and taxi drivers. At the time of fieldwork, average incomes from these sources ranged from about 10 bolivianos ($1.33) to 50 bolivianos ($6.66) a day. As a result, many households struggle to maintain access to food, water, medications, and other necessities (Wutich 2006). The economic stresses on Villa Israel households are intensified by the lack of public infrastructure in the community, including bridges, paved roads, and especially municipal water supply.

In place of the municipal water system, people acquire water from four distinct sources (Wutich 2007). The first is a community-run tapstand system, which distributes groundwater from two wells within Villa Israel. The second is a system of private water trucks, also known as "small-scale private service providers" (Solo 2003), which imports water from outside the community. The third is a seasonal creek, which is an open-access water source with no restrictions on its use. Consequently, creek water is highly contaminated and unfit for drinking. The fourth is a system of reciprocal exchange, in which community members recirculate water from these three sources and rainwater collection amongst themselves. Because of the inadequacy of these water sources, 72% of Villa Israel households lack 50 l of water per person per day (Wutich 2006), the daily allotment needed to maintain minimum consumption and hygienic standards (Gleick 1996).

Before deciding to focus on Villa Israel, I conducted participant observation in several Cochabamba communities that had common pool water resource institutions. I selected Villa Israel as a case study site at least in part because the water-related challenges it faces appeared to be typical of south-side squatter settlements; it was neither a success story nor a disaster. Like resource users in many settlements, Villa Israel residents struggle to maintain the resource and working institutional rules. To better understand these struggles, I conducted an in-depth ethnographic study of Villa Israel's community water system.

## How Villa Israel's Water Institution Functions

### Autonomy, Ownership and Access

Villa Israel's common pool water is supplied from two small hillside wells located a 30-min walk from the community. The water system is autonomous; water from the well is owned by the community itself. According to the president of the Villa Israel Water Committee (Vicente Jorge Apaza, personal communication, 2008), the settlers adapted rural water management principles to create a new set of rules for the management of water in an urban environment. The water system is managed by Villa Israel's local government—called the Neighborhood Council (*Junta Vecinal*)—which also is the primary collective choice arrangement in the community. Only community members are eligible to receive water from the community's wells and to participate in the governance of the water system. Community membership is afforded to households that own land within the formal boundaries of the community and send at least one representative to participate in community governance. As Table 1 shows, 53% of Villa Israel residents are community members. Another 29% can be considered proxy community members as, while they do not legally hold title, they live in a Villa Israel residence, participate in community governance in lieu of the landowner, and are permitted to access the community water system. Proxy community members are often family members who occupy and care for the home in the landowners' absence. Another way to become a proxy community member is to enter into an *anticrético* contract,

**Table 1** Classification of respondents by community membership status

| Membership status | Percent |
|---|---|
| Community members | 53 |
| Proxy community members | 29 |
| Non-community members | 18 |

an arrangement in which title is given as collateral against a large long-term loan. The lender occupies the residence until the loan is repaid and has legal claim to title if the loan is defaulted (Farfan 2004). Because community members and proxy community members are functionally equivalent categories, I group them together in the analyses that follow.

The last group, 18% of Villa Israel's population, comprises people who rent a home or a room in the community. Renters are formally excluded from the rights and responsibilities afforded community members in Villa Israel. The rationale for this is that community members (and their proxies) are required to pay taxes and contribute labor to support local projects such as the construction and maintenance of roadside curbs, soccer fields, and the water system. Once a month, the Neighborhood Council holds an open-air community meeting in which the management of the water system can be discussed and modified. While renters are not physically prevented from attending, they are prohibited from voting. They are also discouraged from attending and voicing their opinions in group discussions. Renters are often, but not always, long-time residents of the community who are unable to afford their own home. As a result, the exclusion of renters prevents some of Villa Israel's more vulnerable residents from participating community governance.

## Proportionality, Uniformity and Contiguity in Water Distribution

Even for eligible community members, there are still several obstacles that must be overcome to gain access to the tapstand system. Each tapstand typically serves 10–20 households located nearby, and not all households have access to a working tapstand. During my field research, the water system delivered water to about 10 tapstands, one new tapstand was built, one was under construction but remained unfinished, one was completely defunct due to siltification, and several zones had no tapstand at all. The responsibility for funding, constructing, and maintaining tapstands falls to user groups. User group organization takes the form of informal interactions among neighbors in a roughly delineated region, rather than a formal organization. The user groups constitute, in essence, a nested enterprise within the Neighborhood Council. At the user group level, the principle of proportionality is followed because people cannot access a tapstand unless they have contributed the funds, materials, and labor required to build or maintain it.

People who are community members, participate in active user groups, and have access to a functional tapstand are still not necessarily able to collect water from the community system. To get access to a local tapstand, community members must also pay a fee of 10 bolivianos ($1.25) every 2 months. Once the fee has been paid, households receive a yellow punch card that gives them the right to access their local tapstand. The tapstand may then be accessed once a day *by each household*. The maximum amount of water allotted, when water is being discharged at full capacity, is 40 l of water per household. This daily allotment system conforms to the uniformity rule, in which everyone is awarded the same water rights and water is distributed with the same frequency to all.

A community elder, chosen because he can live on the modest 450 boliviano ($56.25) monthly stipend paid by the community, is responsible for supervising water distribution. He begins at 4:00 am and unlocks the tapstands one by one. The supervisor follows a strict contiguity rule, in which water is distributed in a set sequence, in 20-min time blocks, between 4:00 am and 9:00 am. Each tapstand is unlocked only once a day, 6 days a week (Sundays excluded). The tapstand supervisor blows a loud whistle to alert local users that their tapstand is about to be opened. Users must show the supervisor their yellow punch card to prove that they have paid their dues. After they collect their water, the supervisor relocks the tapstand and continues on to the next zone. However, due to the year-round problem of water scarcity, the system often goes dry before the supervisor is able to distribute water to all of the community's tapstands. When this occurs, the supervisor begins distributing water the next morning from the point at which water ran out. Because tapstand distribution is reinitiated each day at different points in the community system, community members never know when in the 5-hour time window they will be called to acquire water. This illustrates one of the problems of adopting the contiguity rule in an urban setting, where income generation activities are generally conducted outside of the household and turn-taking can be time-consuming and costly. For families who did not have a full-time homemaker, it was extremely difficult to participate in both water collection and their income-generating activities.

## Equivalence of Costs and Benefits at the Household Level

At this point it should be clear that the costs involved in tapstand use are quite high, raising the question of whether the benefits do, in fact, outweigh the costs in Villa Israel. Community members must attend monthly Neighborhood Council meetings; contribute labor, materials, and money to community-wide and tapstand-level projects; invest up to 5 hour a day waiting to physically acquire the water; and contribute a bimonthly user fee. Since the average household in Villa Israel contains five people, the 40-l household allotment yields, on average, only about 8 l of water per person per day. Even in refugee camps, the World Health Organization recommends that households be

**Table 2** Quantity of water used daily in Villa Israel households

| Water use task | Mean (lpcd) |
|---|---|
| Drinking | 1.5 |
| Cooking | 5.4 |
| Personal hygiene | 9.3 |
| Household task | 26.1 |

provided at least 70 l of water a day (WHO 2005). Given the high costs of tapstand use and the insufficiency of its output for daily survival, it seems that Villa Israel's system does not offer an equivalence of benefits and costs.

I studied Villa Israel households' water use habits to see how they compare with international recommendations (Table 2). Based on self-reported diary data, I found that Villa Israel residents use only 7 l per person per day, on average, for cooking and drinking (Wutich 2009). The tapstands, then, do provide sufficient water for basic subsistence needs—at least for an average family with average water consumption levels. And, indeed, when I asked people how they used water from the tapstand, they nearly always said that they used it for drinking and cooking. In this case, the low opportunity cost of the labor and the high marginal utility of the outcome for those living near subsistence level help to explain why people continue to participate in such a costly system (Chayanov 1966, Scott 1976). The cost–benefit calculus involved in tapstand use seems balanced for Villa Israel residents with low paid labor and modest water needs who are living near subsistence level.

## Regularity and Transparency in a Highly Stressed Urban Water System

Given that people are living so close to subsistence level, we might expect that all kinds of cheating—such as theft and overuse—would be serious problems. If so, defense of the system and its rules must be of the utmost importance. In Villa Israel, monitoring, sanctioning, and conflict resolution occur on four levels. First, the Neighborhood Council is responsible for distributing tapstand punch cards and, if necessary, resolving conflicts at general meetings. The second, and most crucial, level of supervision is the interpersonal one. As dictated in the transparency rule, all community members are responsible for making sure that the rules are followed. As a result, much of the monitoring and sanctioning in the Villa Israel takes the form of gossip and unpleasant visits from neighbors. The third level of supervision, really a special case of the second one, occurs at the tapstand, where people gather in a tight group to watch for rule-breaking by other users. However, justice is not swift. Often, a debate will break out in which people defend the rule or take the side of the rule-breaker. Ultimately, the values of the group and the personal relationships people have with the rule-breaker determine how each violation is treated. The tapstand supervisor, who provides the fourth level of supervision, has the final word on what will be allowed, or not. If there is a clear group consensus, he will conform to it whether it follows the rules or not. If there is not a group consensus, he will use his own discretion (and generally follow the rules) to decide a case. The tapstand supervisor has one more very important role—he monitors the water availability at the wells, and adjusts the allotted output for all tapstand users if the water level is low. This is meant to ensure that the system is not overexploited, and that a proper balance is maintained between resource exploitation and local conditions at the water source.

To see how the system of monitoring, sanctioning, and conflict resolution actually works in practice, I kept records of all of the violations of system rules that I knew of during the fieldwork. I should note that, while we asked over 1,000 survey questions on these topics, respondents admitted that they participated in monitoring, sanctioning, and conflict resolution only four times; underreporting was probably related to the stigma associated with conflict in the community. Respondents were more willing to share stories of their neighbors' experiences with rule-breaking, monitoring, sanctioning, and conflict. Therefore the data I present here are unsystematic, gathered via participant observation and second-hand reports. Figure 1 shows a list of 10 violations of community rules that I documented in Villa Israel. They are arranged from most offensive to least offensive. The violations range from outright theft (which is very rare), to renters receiving water, to legitimate tapstand users being inconsiderate of others. I was particularly interested in the case in which renters receive water from

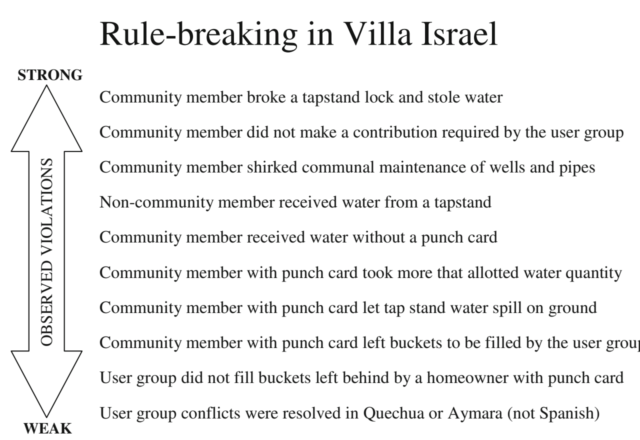


**Fig. 1** Institutional rules broken during the field research, arranged from strongest to weakest rule violation

the tapstand system because it violates two of the rules for Andean irrigation systems: proportionality and regularity. It also indicates that the collective choice, monitoring, and sanctioning systems that undergird the water institution may not be functioning properly. Furthermore, it raises a fundamental question: do community members prioritize the preservation of the system at the cost of household well-being, as the regularity rule suggests, even when households are operating at or below subsistence level?

To explore this, I took a baseline measure of tapstand use in the sample in April and May of 2004, at the onset of the dry season. I found that, across all tapstand users, 85% were legitimate beneficiaries and only 15% were free-riding renters. Overall, this seemed to show that the monitoring and sanctioning system was working reasonably well, though it clearly does not function perfectly. But when water scarcity gets worse—as in the dry season—people's need for water intensifies. Therefore, the questions arises whether the community water system's rules are sustainable during periods of severe urban water scarcity.

## Sustainability of Institutional Rules During Periods of Water Scarcity

In the Cochabamba, there is a pronounced wet season during the summer (November to February) and dry season during winter (May to September). The year in which field research was conducted was typical for a semiarid region, with total annual rainfall of 521 mm (SENAMHI 2006). To establish that intra-annual variation in precipitation is, in fact, linked with water scarcity in Villa Israel, I analyzed household-level data on water insecurity collected over four time periods. The analysis was conducted using a 9-point Guttman scale that measured the extent to which households lacked water to complete tasks such as cooking, bathing, and cleaning. I found that there was a statistically significant difference in water insecurity across the study periods, with high water insecurity between June and September and low water insecurity experienced between October and January (Table 3). Given that water insecurity

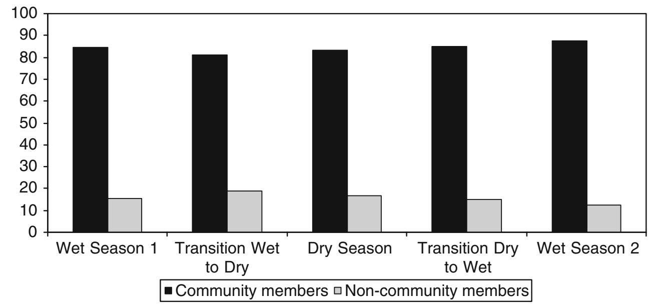


**Fig. 2** Community members and non-community members receiving water from the tapstand system over five seasonal study periods

does intensify during the dry season, we can proceed with an examination of the effects of seasonal water scarcity on community members' enforcement of institutional rules.

As Fig. 2 and Table 4 show, there not much of a difference in free-riding by non-community members during the period of severe seasonal water scarcity. Rather, it seems that legitimate beneficiaries tolerate a low level of free-riding by renters when their need can be verified by some member of the tapstand group, regardless of the season or the severity of water scarcity experienced by the group. Interestingly, as the dry season advanced, cuts were taken uniformly across groups—the daily water allocation was cut from 40 to 20 l per households and affected all households equally. This seems strong evidence that community members uphold the principle of regularity, even in times of severe scarcity. Furthermore, there appeared to be a subsistence ethic in the community that, in some circumstances, allowed all Villa Israel residents (even non-community members) to acquire the minimal amount of water they needed to drink and cook.

While these results seem clear-cut, they do not show the whole picture of social responses to seasonal scarcity. In addition, I was interested in examining whether the nested institutions that support monitoring and sanctioning in the community function the same way during times of severe water scarcity as they do during times of relative water abundance.

**Table 3** Variation in household water insecurity scores over four seasonal periods

| Season | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|
| Wet to dry transition | 3.8 | 2.3 | 0 | 8 |
| Dry season | 3.9 | 2.5 | 0 | 9 |
| Dry to wet transition | 3.5 | 2.7 | 0 | 9 |
| Wet season 2 | 2.8 | 2.7 | 0 | 9 |

$F(3,54)=4.24$, Wilk's lambda=0.81, $p=0.009$, eta squared=0.19

## Sustainability of Nested Institutions During Periods of Stress

To investigate this, I examined, first, participation in the Neighborhood Council, and second, the size of social networks during the five study periods. The Neighborhood Council is the collective choice arrangement associated with the community water system. Social networks provide a way to measure people's engagement in operational rule enforcement.

**Table 4** Percentage of households receiving water from the tapstand system over five seasonal periods, by community membership

| Season | Community members | Non-community members |
|---|---|---|
| Wet season 1 | 84.6 | 15.4 |
| Wet to dry transition | 81.0 | 19.0 |
| Dry season | 83.3 | 16.7 |
| Dry to wet transition | 85.0 | 15.0 |
| Wet season 2 | 87.5 | 12.5 |

## Neighborhood Council

Figure 3 and Table 5 depict the participation of community members and non-community members over the five study periods. As with the test of rule-breaking, I found initially that the monitoring system in the Neighborhood Council was in reasonably good working order at the height of the wet season. While non-community members were not physically excluded from attending, they were actively discouraged from participating in Neighborhood Council meetings. Almost 90% of participants in Neighborhood Council meetings were legitimate community members, not renters. This ensures that non-community members cannot override the will of community members, modify the rules in ways that benefit them, or otherwise abuse the system. However, we can observe two very interesting trends across the five time periods. First, community members' participation in the Neighborhood Council is high during the two wet seasons and drops off consistently during the dry season. Second, the participation of non-community members is low during the wet season but increases steadily during the dry season.

The drop-off in community members' participation is easily explained, and has very little to do with water scarcity. At the second time period, the president of the Neighborhood Council was accused of a serious act of corruption. A major conflict broke out, and several of the meeting's attendees came to blows. Afterwards, disgusted with the whole affair, community members initiated a movement to *desconocer* or impeach the community's president. The movement was successful in fifth time period, when a new president was appointed. The behavior of the renters during this period is particularly interesting. At times when the legitimate government was functioning properly, their participation was low or non-existent. But when corruption and political instability created an opportunity for exploitation, they appeared to make the most of it, seeking to increase their influence in the community and possibly their access to the tapstand system. At the same time, the attendance of community members dropped off as they protested the old administration. As a result, the attendance of non-community members rose drastically in proportion to the attendance of community members. However, once the Neighborhood Council was reestablished and in working order, non-community members were effectively excluded once again.

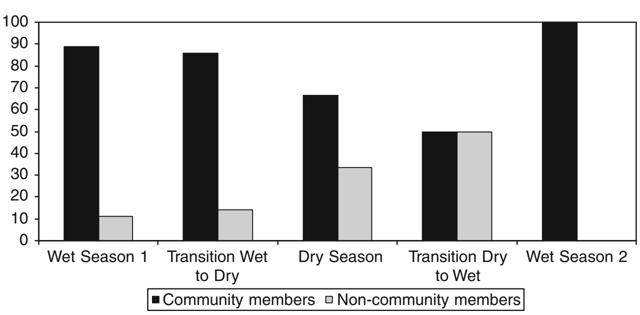


**Fig. 3** Community members and non-community members participating in Neighborhood Council meetings over five seasonal study periods

## Social Networks

While internal conflicts and power struggles created an opening for non-community members to participate in the Neighborhood Council, I wanted to explore what was happening within the social networks that act as gatekeepers for the operational rules at the tapstands. To do so, I collected a baseline measure of the interpersonal interactions through which the bulk of monitoring and sanctioning is conducted in Villa Israel. I envision these interpersonal interactions as social networks, in which the size of each person's network determines their ability to enforce operational rules—or to break them with impunity. While personal network size can be measured in a number of ways, I use a measure of food-sharing ties here. Food sharing is a very important symbolic activity in Villa Israel, in which small amounts of food (e.g., a wedge of orange) are offered to reaffirm ties, build rapport, or smooth over rocky relations. This measure is a useful one because it provides a more sensitive measure of personal network activity than simply counting the number of people a Villa Israel resident knows.

The trend in seasonal changes in social networks is very different from that of Neighborhood Council attendance. The results of a repeated measures ANOVA indicate that there is a statistically significant difference in personal network size across the five time periods, with a large and

**Table 5** Percentage of respondents attending Neighborhood Council meetings over five seasonal periods, by community membership

| Season | Community members | Non-community members |
|---|---|---|
| Wet season 1 | 88.8 | 11.1 |
| Wet to dry transition | 85.7 | 14.3 |
| Dry season | 86.7 | 33.3 |
| Dry to wet transition | 50.0 | 50.0 |
| Wet season 2 | 100.0 | 0.0 |

significant effect for time (Table 6). There was a spike in network activity across all groups as the dry season kicked in, as people tried to mobilize their networks to attain more resources (Fig. 4). Then, as the dry season advanced, network activity dropped off as people increasingly tried to protect and conserve their resources. When the dry season ended, social activity increased again. Based on theories of social response to severe resource scarcity (Laughlin and Brady 1978, Dirks 1980), this result is expected because people withdraw from social relationships during times of scarcity so that they can minimize their social obligations to help others obtain resources. It is interesting to note that, while we see this general pattern across all Villa Israel residents, non-community members' networks are always smaller than those of community members. A *t*-test comparing the average network size over the five study periods showed that community members' networks were significantly larger than those of non-community members (Table 7). As we would expect, community members have larger social networks (and thus more interpersonal influence in the community) than non-community members. However, a split-plot repeated measures ANOVA shows that there was no significant difference in the interaction between time and respondents' community membership (Table 8). These results indicate that social exclusion was present at all times, but this did not appear to be heightened during periods of severe resource scarcity.

The overall evidence indicates that non-community members were excluded from the community water system and personal networks throughout the five study periods, and that they were excluded from the Neighborhood Council when it was functioning properly. While there is no evidence that social exclusion increased during the dry season, there was evidence that exclusion had more severe impacts on non-community members during periods of severe seasonal water scarcity. For example, one family that agreed to participate in the study had been renting a house in Villa Israel for only 8 months. As the dry season progressed, the family complained more and more of not being able to make ends meet; they lacked money for water, for ingredients to make the gelatin desserts they sold in the downtown market, and for transportation to the city center. The household head complained that, as water became scarcer, she had nobody she could turn to for help in the community—no one would lend her water or help her get access to the community system. She mentioned that they could not last much longer with the debts piling up, and that she and her husband were thinking of moving away. By the third round of interviews, the family was no longer living in Villa Israel. This example illustrates how trade-offs are made between vulnerabilities at the level of the community water system and individual households. While the water system weathered the dry season intact, not all households were able to do so.

**Table 6** *T*-test comparing social network sizes for community members and non-community members

| | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|
| Community members | 11.1 | 9.6 | 0 | 34.2 |
| Non-community members | 6.0 | 4.1 | 0 | 11.8 |

$t(55)=3.17$, $p=0.002$

## Discussion and Conclusions

Based on the data presented here, we can draw some conclusions about the sustainability of Villa Israel's CPR institution in the face of the intra-annual climatic variability. First, the system is managed according to the principles of uniformity, contiguity, and proportionality, which ensures that all eligible community members receive fair and equal access to water from the tapstand system. These rules are enforced via monitoring and sanctioning, yet it appears that

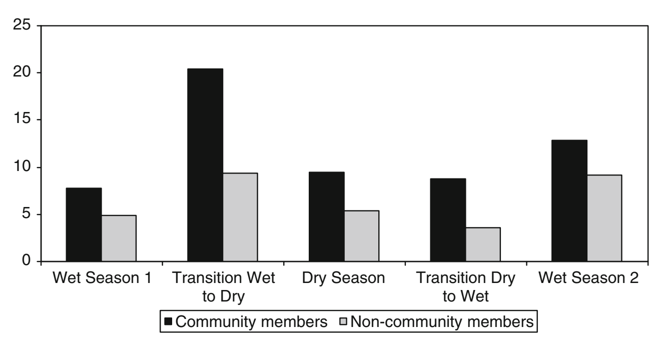


**Fig. 4** Average network size of community members and non-community members over five seasonal study periods

**Table 7** Repeated measures ANOVA comparing social network sizes over five seasonal periods

| Season | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|
| Wet season 1 | 8.0 | 12.0 | 0 | 59 |
| Wet to dry transition | 19.8 | 29.3 | 0 | 149 |
| Dry season | 9.8 | 13.1 | 0 | 68 |
| Dry to wet transition | 6.8 | 9.0 | 0 | 94 |
| Wet season 2 | 13.0 | 17.6 | 0 | 100 |

$F(4,53)=4.09$, Wilk's lambda=0.76, $p=0.006$, eta squared=0.24

a small amount of free-riding is tolerated in order to help some households meet short-term subsistence needs. Second, the system is governed following the principle of regularity. This is particularly important during times of scarcity, when water use must be cut back to prevent overexploitation of the common pool water resource. The regularity principle ensures that water cutbacks are apportioned to all community members equally. Third, while the function of the CPR institution was stable over the five study periods, the social structures that underlie it were noticeably more sensitive to external events. Activity in the nested institutions that organized collective choice (the Neighborhood Council) and oversaw operational rules (social networks) fluctuated in patterned ways over the five study periods, and there is some evidence that seasonal water scarcity played a role in those fluctuations. The results suggest that while institutions with strong historical precedents for contingencies under resource stress can weather periods of scarcity intact the nested institutions that organize collective choice and operational rules may not be as robust to external stressors.

While the focus of this study was intra-annual climatic variability, the results may shed light on the sustainability of CPR institutions under conditions of global climate change. The findings suggest that long-enduring CPR institutions have contingency rules that enhance their sustainability during severe resource stress. In Villa Israel, flexible rules for water allotment allowed the CPR to be managed adaptively in response to dry season stress; yet the adoption of flexible rules designed to protect the resource did not undermine fairness, equity, and the subsistence ethic—the norms that ensured the social acceptability of the system. This indicates that a well-organized CPR institution may have the ability to remain ecologically and socially sustainable during periods of stress and uncertainty. One factor identified here, however, may undermine the adaptive capacity of CPR institutions. In Villa Israel, the nested institutions that organized collective choice and operational rules were highly disrupted by external stressors; this may create vulnerability in an otherwise sustainable CPR institution. For instance, when nested institutions for collective choice are disrupted by corruption, this may result in tolerance of self-interested rule-breaking or the adoption of rules that threaten sustainable resource governance. Indeed, Scott's (1976) research on the moral economy of food-insecure peasants demonstrated that the adoption of self-interested norm-breaking rules at higher levels of governance ultimately led to collapses at lower levels. For long-enduring CPR institutions to be sustainable during periods of global climate change, it may be particularly important to protect them from disruptions in nested institutions. For squatter settlements and other impoverished communities, many of which already struggle to survive in the face of vast political, economic, and ecological inequities, insulation from macro-political turmoil may be essential for the sustainability of local CPR institutions.

This study makes two additional theoretical contributions. First, the findings indicate that Trawick's principles for long-enduring Andean irrigation institutions were present in an urban setting. This provides some evidence in support of Trawick's argument that Andean CPR management principles are embedded in cultural knowledge passed down through the generations; the findings in Villa Israel also indicate that such knowledge is passed from rural to urban communities. Additionally, this study demonstrates that the principles of Andean CPR institutions

**Table 8** Spit-plot repeated measures ANOVA comparing social network sizes between community members and non-community members over five seasonal periods

| Season | Mean | Std. dev. | Min. | Max. |
|---|---|---|---|---|
| Wet season 1 | Community members | 8.6 | 12.7 | 59 |
| | Non-community members | 4.4 | 5.9 | 17 |
| Wet to dry transition | Community members | 20.9 | 31.5 | 149 |
| | Non-community members | 14.0 | 11.3 | 32 |
| Dry season | Community members | 10.5 | 14.0 | 68 |
| | Non-community members | 6.0 | 5.3 | 15 |
| Dry to wet transition | Community members | 7.3 | 9.5 | 94 |
| | Non-community members | 4.6 | 5.8 | 13 |
| Wet season 2 | Community members | 13.7 | 18.9 | 100 |
| | Non-community members | 9.2 | 6.9 | 19 |

$F(4,52)=0.09$, Wilk's lambda= 0.99, $p=0.99$, eta squared=0.01

can endure in communities suffering from more severe water scarcity than is typically found in rural irrigation communities. This is noteworthy because it proves that community members do, in fact, prioritize the preservation of the system over the well-being of individual households under conditions of severe water scarcity. Second, this study suggests the need for more research on the dynamics of nested institutions. Ostrom's "design principles" establish that nested institutions for resource management, collective choice, and oversight of operational rules are crucial for sustainable commons governance. While a number of scholars have examined how polycentric and nested institutions contribute to CPR management (cf. McGinnis 1999; Ostrom 1999), few have examined how the success of sustainable CPR institutions is affected by disturbances in nested governance institutions. In Villa Israel, the institutions overseeing collective choice and operational rules faced major challenges—corruption and water scarcity, respectively—that disrupted their normal function. However, these disruptions had no visible effect on the function of Villa Israel's common pool water resource institution. Yet there are likely thresholds at which disruptions in polycentric and nested institutions begin to directly affect CPR institutions; if so, this study points to the need for more research on when such thresholds emerge and what makes some CPR institutions robust to such disturbances.

Several limitations should be considered when interpreting these findings and planning future studies. The data were based on respondents' retrospective reports of their participation in water collection, local government, and social interactions. Consequently, some responses may have been inaccurate due to recall bias or deference effects. To minimize these response errors, binary data (rather than frequencies) were collected for questions regarding the use of the water system and attendance at local government meetings. As a result, however, the analyses of seasonal patterns in water system use and attendance at government meetings employed descriptive rather than inferential statistics. Observational methods may yield more reliable and precise measurements of households' engagement in local institutions. This will be particularly important for future research directions suggested by this study.

One particularly timely topic for future research is the success of different water institutions under diverse social and ecological conditions. Two recent trends have created an opening—and even a demand—for this kind of research. First, there is now a consensus that climate change is real and obliges us to reevaluate the ways in which water institutions operate around the world (Lenton 2004; Muller 2007). Planners and policymakers are in need of more information about the performance of water institutions under climatic variability and uncertainty. Second, the international development community's renewed interest in smaller-scale water provision solutions, as opposed to large-scale privatization schemes, creates an audience for research on institutional diversity in water provision, particularly in urban settings (Budds and McGranahan 2003; Ho 2003). Social scientists whose work has a cross-cultural and wide historical scope are well positioned to meet these research needs. Another important area of research will examine the sustainability of institutions that violate the tenets of self-interest and strict economic rationality, such as CPR institutions and reciprocal exchange systems. Such systems are generally understood to thrive under conditions of *moderate* resource scarcity (Cashdan 1985), yet we do not fully understand how they are affected by conditions of *severe* resource scarcity. While recent research seems to indicate that severe resource scarcity provokes self-interested behavior that undermines such systems (Moser 1996; González de la Rocha 2001), there is a dearth of comparative longitudinal data that examine the question. Finally, there is a need for more research that examines the dynamics of nested institutions. As new methodological approaches develop, particularly social network methods for studying innovation, diffusion, and collapse, we may be able to examine questions of structure, scale, and complexity in more sophisticated ways than ever before (White 2002; Goldstone and Janssen 2005). The question of how collapses and thresholds, as well as innovation and diffusion, affect different institutional practices may reveal much about the vulnerability, resilience, and sustainability of socioecological systems.

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## Appendix—Excerpt of Survey Questionnaire

Water Insecurity Questions:

1. In the last week, were you unable to cook because you didn't have enough water? (Yes/No)
2. In the last week, were you unable to bathe because you didn't have enough water? (Yes/No)
3. In the last week, were you unable to clean the house because you didn't have enough water? (Yes/No)

4. In the last week, were you unable to do the dishes because you didn't have enough water? (Yes/No)
5. In the last week, were you unable to wash laundry because you didn't have enough water? (Yes/No)
6. In the last week, did you cut back on water use when bathing? (Yes/No)
7. In the last week, did you cut back on water use when cleaning the house (i.e., mopping)? (Yes/No)
8. In the last week, did you cut back on water use when washing the laundry? (Yes/No)
9. In the last week, did you cut back on water use when cooking? (Yes/No)

Homeowner Question:
Is the place where you are living your own home, rented, borrowed/shared, or in *anticrético*?

a. Own home
b. Rent
c. Borrow or share home
d. *Anticrético* (an arrangement in which a home title is given as collateral against a loan)

Tapstand Use Question:
Did you acquire water from the tapstand in the last week? (Yes/No)

Neighborhood Council Question:
Did you attend a neighborhood committee meeting in the last week? (Yes/No)

Social Network Questions (adapted from Stack 1974), related to food exchanges:

1. Who did you see or visit in the last week—which relatives, neighbors? Did you exchange food with this person? If so, did you give food or receive it?
2. With whom did you spend your days over the last week? Did you exchange food with this person? If so, did you give food or receive it?
3. Where and with whom do you eat breakfast, lunch, dinner over the last week? Did you exchange food with this person? If so, did you give food or receive it?
4. What work did you do? With whom do you work? Did you exchange food with this person? If so, did you give food or receive it?
5. With whom did you enjoy spending time over the last week? Did you exchange food with this person? If so, did you give food or receive it?
6. With whom do you participate in group activities over the last week (church groups, soccer or basketball, paid work, community work projects, etc.)? Did you exchange food with this person? If so, did you give food or receive it?
7. Who did you sit or visit with at neighborhood activities—soccer games, church, neighborhood committee meetings, other events—over the last week? Did you exchange food with this person? If so, did you give food or receive it?

Probing instructions:
Probe repeatedly—explore who they visit, which people they see daily or weekly, what they do for each other, whether they exchange food or other goods, and how these exchanges are arranged.

Selected Variable Calculations:
Determining community members and non-community members:
If (Homeowner Q = a, c, or d), then classify respondent as a community member.
If (Homeowner Q = b), then classify respondent as a non-community member.

Determining legitimate beneficiaries and free riders:
If (Homeowner Q = a, c, or d) and (Tapstand Q = Yes), then classify respondent as legitimate beneficiary.
If (Homeowner Q = b) and (Tapstand Q = Yes), then classify respondent as free rider.
If (Tapstand Q = No), then exclude respondent from analysis of tapstand use.

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