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Community initiatives in building and managing temporary check-dams across seasonal streams for water harvesting in South India

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ABSTRACT

We analyze traditional community initiatives in building and managing temporary check-dams across seasonal streams in Kumbadaje panchayat in the state of Kerala in India. This is a fairly successful system, functioning for decades in the study area. Check-dams overcome water scarcity faced by farmers during the summer irrigation season and thereby play a crucial role in farming. We identify issues in the management of check-dams, noting how this traditional water harvesting and conservation system suits the local geographic conditions and needs to be sustained and promoted.

1. Introduction

Traditional water harvesting systems can alleviate the problem of water scarcity experienced in parts of India. In recent years, there has been a resurgence and revival of these systems. Many traditional water harvesting systems involve collective and participatory management of water resources by users. Collective and participatory management has contributed to the success of temporary check-dams built across seasonal streams by informal farmers' groups in northern parts of Kerala state and southern parts of Karnataka state in South India (Raghuram, 2004). Similar check-dams known as *bandharas* are constructed and maintained by farmers in the Western Deccan region of Maharashtra state across rivers and streams for irrigation during the dry season (Agarwal and Narain, 1997).

Check-dams are small barriers built across the direction of water flow on shallow rivers and streams for the purpose of water harvesting. Check-dams have been functioning for decades in Northern Kerala and Southern Karnataka as a solution for water scarcity faced by farmers in summer. Collective action is encountered at all stages, from planning and construction, to demolition of temporary check-dams, without any technical or financial backing from the state. Check-dams suit Indian conditions, where a large number of seasonal streams completely dry up during summer. The

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success of such collective traditional water harvesting systems in ensuring sustainable water supply in different parts of India has gained the interest and promotion of the Government of India. The National Water Policy, 2002 of India recommends the revival of traditional water harvesting systems to increase utilizable water resources (Ministry of Water Resources, 2002). Such policy measures are gaining acceptance due to the realization that major and medium irrigation projects constructed in the past and managed by government agencies have invited criticism on economic and ecological fronts (Engineer, 1990; Kothari, 1998; Paranjpye, 1990; Sharma, 1999; Nair, 2002; Raghunath, 2003). Traditional water harvesting systems enhance the water status of a country and contribute to achieving sustainable development.

We highlight the importance of temporary check-dams in the agrarian economy and describe the need to study such systems to bring them to the notice of policy makers. We analyze the collective initiatives in building and managing temporary check-dams (*kattas* in vernacular language) by informal farmers' groups in the Kasaragod district of Kerala state in South India. Our goals are to explore the process of collective participatory management of check-dams and to identify important management issues.

2. Scope of the study and research method

A case study was conducted in Kumbadaje panchayat in Kasaragod district, where the primary water sources include one river and twenty seasonal streams. Farmers construct more than 40 check-dams across these streams every year (Fig. 1). We selected a random sample of ten check-dams from three seasonal streams; four from Mallara-Berakkadavu, three from Kaleyathodi-Odamballe and three from Nerappadi-Odamgellu. Of the three streams, the first two merge at Nerappadi in Kumbadaje. The three streams were selected intentionally, as the time of construction of check-dams on the Nerappadi-Odamgellu stream depends on the construction of check-dams on the other two streams—a vital factor in the success of this traditional water harvesting system.

We assign the letters A to J to denote the ten check-dams. The number of farmers sharing each check-dam ranges from 4 to 16 (Table 1).

We collected data in two stages. The first stage involved secondary data collection from relevant government agencies such as Krishi Bhavan and the Kumbadaje Panchayat Office to gather background information on the study area. In the second stage, primary data were collected using a structured, pre-tested questionnaire. We collected original data from 66 farmers, living on either side of the check-dams. The farmers described their land holdings and cropping patterns, their irrigation methods, with emphasis on check-dams, and their contribution and participation in building and demolition of check-dams. The farmers also described other management aspects such as the water distribution mechanism, the adequacy of water supply, the presence or absence of free riders, and the role and effectiveness of the heads of farmers' groups. We obtained information from the head of farmers' groups describing check-dam dimensions, the raw-materials used for construction, construction cost, technical expertise, problems encountered in building and managing check-dams, coordination with other check-dams, and government support, if any.

Fig. 1 – Temporary check-dam built across a seasonal stream in the Kumbadaje panchayat.

3. Profile of the study area

Kasaragod district lies on the northwestern coast of Kerala state. Our study area, the Kumbadaje panchayat in Kasaragod district has a land area of 3110 ha, comprised of lowland and upland areas. Areca-nut and cashew-nut are grown in the uplands, while paddy is grown in the lowlands. Banana is

Table 1 – List of sample check-dams and number of farmers

Sample check-dams	Stream	Number of farmers/beneficiaries of check-dam
Mallara (A)	Mallara-Berakkadavu	5
Kattedakorikkar (B)	Mallara-Berakkadavu	4
Kudingela (C)	Mallara-Berakkadavu	4
Berakkadavu (D)	Mallara-Berakkadavu	13
Nerappadi (E)	Nerappadi-Odemgellu	4
Keerikkadu (F)	Mallara-Berakkadavu	16
Odamgellu (G)	Mallara-Berakkadavu	6
Kaleyathodi (H)	Kaleyathodi-Odamballe	5
Kallakatta (I)	Kaleyathodi-Odamballe	5
Odamballe (J)	Kaleyathodi-Odamballe	4

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Table 2 – Land use pattern of farmers in sample check-dams

	A	B	C	D	E	F	G	H	I	J
Total number of farmers	5	4	4	13	4	16	6	5	5	4
Total private land (ha)	17	18	20	26	10	33	17	14	5	4
Average landholding (ha)	3	5	5	2	3	2	3	3	1	1
Classification of farmers according to landholding size[a]										
- Marginal	1	0	0	5	0	8	1	1	2	3
- Small	1	1	0	6	4	4	3	2	3	1
- Medium	3	3	4	2	0	4	2	2	0	0

[a] In India, operational landholdings are classified into four categories depending on their size: marginal (below 1 ha), small (1–4 ha), medium (4–10 ha) and large (10 ha and above) (Government of India, 1995).

cultivated in both the lowlands and uplands. The cropping pattern in the region has changed over the years. According to Balakrishna Rai, a farmer from Kumbadaje panchayat, there has been a prominent shift from paddy to perennial crops such as areca-nut during the last four decades. These perennial crops require assured irrigation throughout the year. The panchayat receives an average annual rainfall of 3250 mm, about 90% of which is received during June to October. But the non-availability of water during the dry spell, which lasts for nearly half the year, limits the cultivation of perennial crops. The study area might be described as a situation of water scarcity amidst plenty of rainfall, as in other parts of Kerala (Basak, 1998).

This situation highlights the importance of check-dams and other traditional water harvesting systems in Kumbadaje. The widespread use of check-dams for irrigation in Kumbadaje panchayat has much to do with the background of the residents. More than half of the sample farmers (69%) are Brahmins (one of the classical four tiers in the hierarchy of traditional Hindu society), who are originally from the neighbouring Dakshin Kannad district of Karnataka state, where check-dams are an important source of irrigation.

Kumbadaje panchayat has 1975 households, most of which depend on agriculture for their livelihood. The sample farmers are classified into marginal, small and medium, based on their landholding size (Table 2). There is a somewhat uniform distribution of farmers in each category in the Kumbadaje panchayat.

4. Analysis

Check-dams have made a significant contribution to the sustainability and profitability of agriculture in the Kumbadaje panchayat. According to Chandrasekhar Bhatt, a local farmer, for every 100 Indian Rupees (INR) of returns from crops, only INR 3 must be spent to construct and maintain a check-dam. However, if no such investment is made, the returns are only INR 25. If temporary check-dams are not constructed, crops cannot be irrigated during summer, as water would flow only until January in seasonal streams, and thereafter water would not be available for irrigation. Check-dams provide stored water for irrigation up to the middle of April and after that, water is made available by digging wells in the streambed. However, in case of reduced rainfall in one year or prolonged drought, check-dams built on seasonal streams in Kumbadaje become ineffective. In such conditions, farmers dependent on check-dams for irrigation suffer a setback, as they cannot immediately switch to an alternative irrigation source.

The farmers revealed that check-dams increase the ground water level, decelerate soil erosion and help to increase crop yields. Agarwal and Narain (1997) observed a similar situation in Hivare, a drought prone village near Pune in Maharashtra in Western India. The success of this traditional water harvesting structure can be attributed to the collective action encountered at every stage—construction, maintenance, and the demolition of check-dams.

4.1. *Construction of check-dams*

The farmers we interviewed described three types of check-dams—temporary check-dams, which are constructed every year, semi-permanent check-dams, with a concrete structure at the base and permanent check-dams, with concrete pillars. The construction, use of water, and demolition of temporary check-dams are repeated each year in Kumbadaje (Fig. 2).

Temporary check-dams are constructed with locally available materials. Construction begins at the end of November and is completed by late December. Laterite soil is processed (locally known as *melpu*) and placed in front of huge boulders, with an emergency outlet at the middle or at the sides (Fig. 3). The cost of constructing a check-dam is between INR 25,000 and INR 30,000 (US$ 1 = INR 42).

A semi-permanent check-dam is constructed yearly on top of a permanent foundation, also known as an apron. Government funds are made available for constructing the foundation. However, the permanent foundations are not completely effective as they increase sedimentation (discussed later). For a permanent check-dam, wooden planks are placed in grooves provided in the concrete pillars, between which processed soil is placed. The construction cost for such a permanent structure is between INR 500,000 and INR 800,000.

In 50% of the check-dams under study, farmers use the traditional method of construction, in which soil and boulders are the only raw materials.

4.2. *Management of check-dams*

Check-dams are integrated into agrarian life in Kumbadaje panchayat. Check-dams are built by collective action and therefore, we focus on the collective management of these

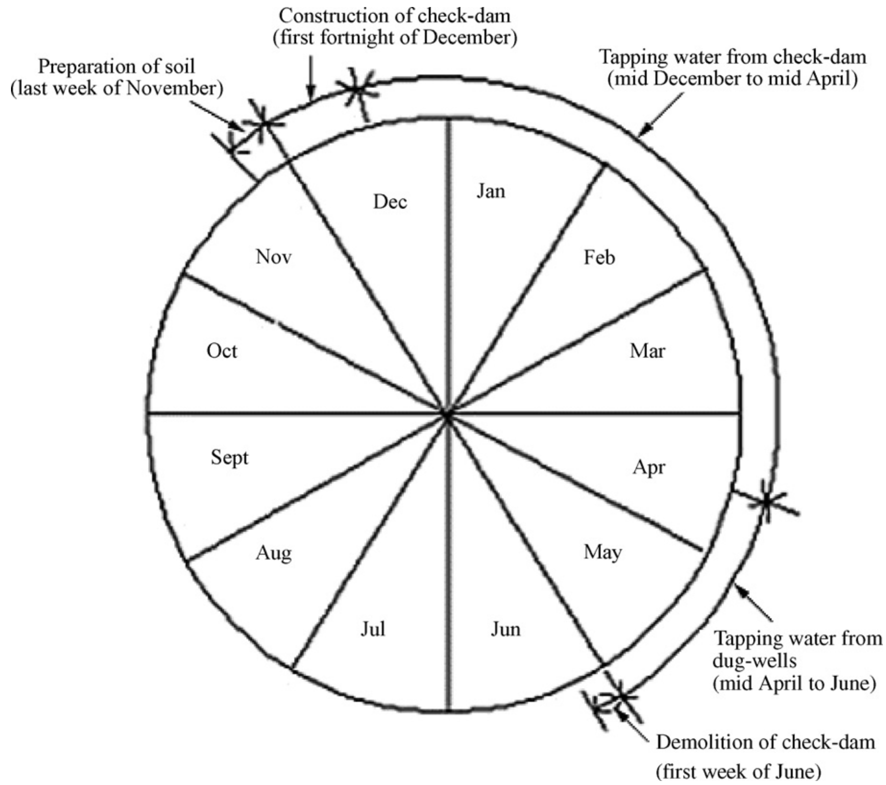

Fig. 2 – A cyclic representation of construction, use and demolition profile of check-dams.

structures in our study. Vermillion (1999), drawing from Ostrom (1990), has classified three types of collective action observed in participatory irrigation management: constitutional actions—observed at the initial/organizing stage; collective choice—formulation of rules and sanctions that describe the functioning of the system; and operational actions, which are observed at the functioning stage. Limited information is available describing constitutional actions pertaining to check-dams, as this system has been in existence for many decades. Strict rules are lacking in the management of check-dams, therefore giving less importance to collective choice. Operational actions are more important, as these are essential elements of the successful management of check-dams.

Fig. 3 – Construction of temporary check-dam underway.

4.2.1. *Farmers' groups*

The farmers (the beneficiaries) belonging to a check-dam who own agricultural fields on either side of the stream have formed informal/unregistered groups for construction and management of check-dams. As an example, the layout of check-dam D (Berakkadavu) and the agricultural fields of its beneficiaries (assigned number 1–13) are depicted in Fig. 4. This check-dam, built across the Mallara-Berakkadavu stream, irrigates agricultural fields up to a distance of 960 m and is the largest of the sample check-dams.

Each farmers' group in the study area has a head, who is also called the convenor, who is responsible for organizing all activities related to the check-dams. The heads arrange the meetings, which are conducted even before the start of construction. They are responsible also for collecting the financial and labour resources required for construction, and maintaining regular communication with the heads of other check-dams to coordinate construction efforts.

The heads dominate the decision making process, which can be attributed to their landholding size. In 90% of the check-dams, the heads have the largest landholding size in their farmers' groups (Table 3). In 60% of the check-dams, heads have more than 4 ha of land. Generally forward classes of the society have more land and they are more influential in community activities. The relatively large landholding of a farmer generally implies enhanced social status in Indian villages.

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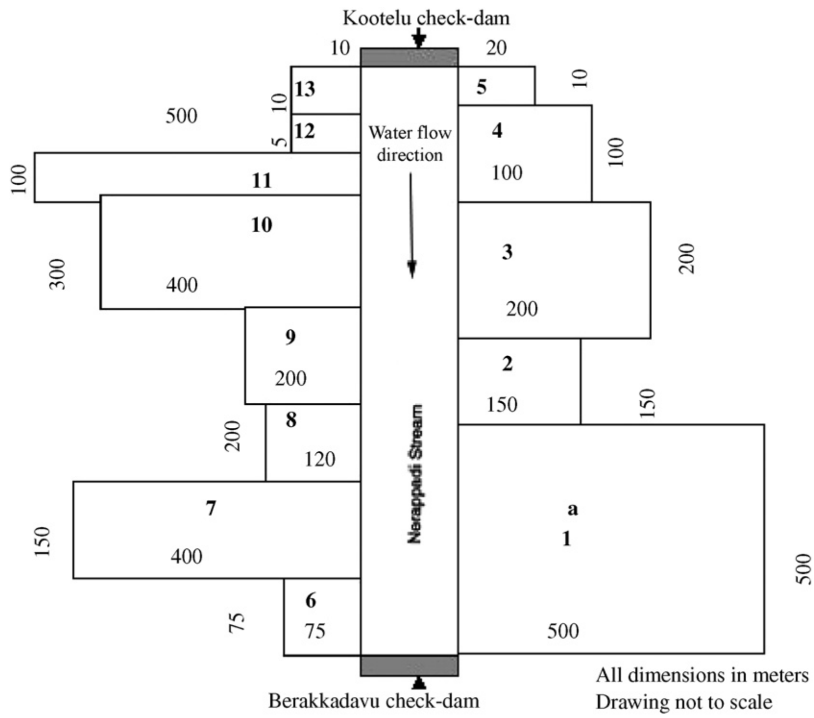

Fig. 4 – Layout of agricultural fields of 13 stakeholders of Check-dam D (*Berakkadavu*). [a]User number.

Heads of farmers' groups generally have more education than other farmers and, hence, they are better qualified to provide the necessary leadership. The high literacy rate (89.7%) among sample farmers augments their specialized knowledge in the management of check-dams.

4.2.2. *Participation of farmers*

The key factor in the success of any community-managed resource is the involvement of its users. In the case of check-dams, management activities should begin even before construction starts, to discuss matters concerning construction, such as sharing the costs and arranging labour. However, in half of the check-dams (A, B, H, I and J) surveyed, the farmers never meet. The reason, as revealed by the farmers, is that construction of check-dams has become routine and hence meetings are not necessary. The participation of farmers in the decision-making process in sample check-dams is shown in Table 4.

Farmers in check-dams E and G were most active, as they regularly meet even after construction of the check-dam. In check-dam E, all farmers participate. Participation was less in check-dam F, with only three (including the head of the farmers' group) of sixteen members attending meetings. Other members have consented that these three members have the right to take decisions on matters regarding construction, and the rest will contribute their share in the cost of construction. Also, in groups whose members are from the same family, no formal meetings are organized.

Table 4 reveals that the farmers' groups arranging formal meetings have larger check-dams and hence have greater water holding capacity. Consequently, such structures are likely to incur more damages during instances of heavy rainfall. Therefore, farmers pay greater attention to their management. In addition, such structures need more capital investment for construction. Accordingly, the share of an individual farmer is high, which acts as an incentive for increased participation.

Table 3 – Landholding pattern of farmers in the respective sample check-dams (ha)

Check-dam	Average landholding	Maximum landholding	Minimum landholding
A	3	6 (Head of farmers' group)	0.8
B	5	6.5 (Head of farmers' group)	1.1
C	5	5.7 (Member of farmers' group)	4.1
D	2	4.9 (Head of farmers' group)	0.3
E	3	3 (Head of farmers' group)	1.3
F	2	5.7 (Head of farmers' group)	0.4
G	3	6 (Head of farmers' group)	0.8
H	3	5.3 (Head of farmers' group)	0.7
I	1	1.3 (Head of farmers' group)	0.4
J	1	1.6 (Head of farmers' group)	0.8

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Table 4 – Participation, dimensions and approximate construction cost of sample check-dams[a]

Check-dam	Number of farmers	Participation of farmers in decision making (%)	Area irrigated (ha)	Dimensions[b] (m)				Type of check-dam	Construction cost per annum (Indian Rupees)
					Width				
				Length	Bottom	Top	Height		
A	5	0	6 (34.9)[c]	15	3	1	3	Temporary	20,500
B	4	0	7 (38.3)	15	2.7	0.6	3	Temporary	23,500
C	4	50	9 (46.7)	20	2	1	3	Temporary	22,500
D	13	54	13 (50)	31.5	4.5	1.2	3.9	Temporary	28,550
E	4	100	7 (71.4)	30	2	1.2	2.5	Temporary	22,800
F	16	19	15 (44.5)	30	3	1	3	Semi-permanent	25,503
G	6	83	9 (52.3)	30	3.9	1.8	3	Temporary	26,250
H	5	0	7 (46.9)	12	3	1	3	Temporary	15,100
I	5	0	3 (71.2)	14	1.5	1	2.5	Temporary	4,500
J	4	0	4 (100)	15	1.5	1	2.5	Temporary	10,000

[a] Analysis based on personal interviews with each of the 66 sample farmers.
[b] Various measurements of each of the sample check-dam were provided by head of farmers' group and also verified by the researchers.
[c] Figures in parenthesis indicate the percentage of total landholding irrigation/cultivation; irrigated land is the same as that under cultivation.

Another factor influencing arrangement of meetings is the command area of check-dams. The relation is positive, but that does not ensure high participation of members. In check-dam F, which has the largest irrigated area, participation by farmers is less than for other check-dams.

4.2.3. *Resource mobilization*

Resource mobilization involves raising the required capital and obtaining labour and raw materials. We hypothesized that 'there is a systematic way of sharing the costs incurred in construction of a check-dam amongst its users'. Our results suggest that the sharing of the construction cost of check-dams is determined by three factors: landholding size, distance of the users from a check-dam, and kinship. The first two factors are greater determinants in apportioning construction cost.

4.2.3.1. *Landholding size*. Landholding size is the most significant factor in determining the share of construction cost borne by each farmer. In most of the check-dams, a large portion of the cost is borne by those who have comparatively large landholdings. Such an arrangement has also been observed in the Philippines, where under the *zanjera* irrigation system, resource mobilization is in accordance with the landholding pattern of the users (Cruz, 1991). However, we observed variations in the arrangements in this study. In check-dam J, all the members are from the same family and the apportioning is done purely on the basis of landholding size. In check-dam I, all the five members have decided to contribute equally to the construction cost (20% each), irrespective of their landholding size.

In check-dam B, cost sharing is determined by kinship factor. Three out of four members are from the same family. Every year, one of the three contributes 90% of the cost. The other farmer, who is not a member of the same family, contributes a fixed amount of INR 2500 every year. In check-dam C, even though one of the farmers owns 4 ha, only 1 ha of it is irrigated. This farmer contributes 13% of the construction cost.

4.2.3.2. *Distance of users from a check-dam*. The distance of agricultural fields from a check-dam affects the water availability for irrigation. Recession of water starts from the tail end, so the temporal water accessibility of tail end users is comparatively limited. Accordingly, their share in costs should be less in comparison with others. However, only 30% of check-dams consider this factor in addition to landholding size, in determining the cost share of farmers.

In check-dam F, there is a very elaborate way of sharing the construction cost. Of the check-dams we studied, check-dam F irrigates the largest area (15 ha) and has the most farmers (16). However, the proportion of land area irrigated is comparatively small (45%). The irrigated area is divided into four zones based on the distance from the check-dam. Zone 1 is the area closest to check-dam and zone 4 is the area farthest from the check-dam. The farmers have formed a concept of "standard hectares", which constitute a percentage of the actual irrigated area.

Suppose $a_1, a_2, \ldots, a_n$ represent the irrigated areas of farmers in zone 1, $b_1, b_2, \ldots, b_n$ represent the irrigated areas of farmers in zone 2, $c_1, c_2, \ldots, c_n$ represent the irrigated areas of farmers in zone 3 and $d_1, d_2, \ldots, d_n$ represent the irrigated areas of farmers in zone 4.

Then, the total standard hectares in each zone are determined as follows:

For zone 1, $A = 1.00\,(a_1 + a_2 + \cdots + a_n)$
For zone 2, $B = 0.75\,(b_1 + b_2 + \cdots + b_n)$
For zone3, $C = 0.50\,(c_1 + c_2 + \cdots + c_n)$
For zone 4, $D = 0.25\,(d_1 + d_2 + \cdots + d_n)$

Suppose TCC represents the total construction cost of the check-dam. The contribution of each farmer toward construction cost is determined as follows:

Farmer i in zone 1 = $[\mathrm{TCC}/(A + B + C + D)] \times a_i$
Farmer i in zone 2 = $[\mathrm{TCC}/(A + B + C + D)] \times 0.75\, b_i$
Farmer i in zone 3 = $[\mathrm{TCC}/(A + B + C + D)] \times 0.50\, c_i$
Farmer i in zone 4 = $[\mathrm{TCC}/(A + B + C + D)] \times 0.25\, d_i$

4.2.3.3. *Mobilizing labour and raw-material*. In the past, many farmers contributed their own labour in the construction of check-dams. More recently, farmers have hired construction labour. The responsibility for arranging labour rests with the head of the farmers' group. In our sample, farmers contributed labour for construction in only two check-dams. Farmers also donate the raw materials and tools needed for construction. The soil needed for construction is taken from the land bordering a check-dam. The boulders used for construction are collected and reused every year. Farmers also share the labour required for demolition of check-dams. Most check-dams in our study were not demolished at the beginning of the monsoon, resulting in soil being carried away by running water. The construction cost is then increased, as additional cost is incurred in removing the accumulated silt and arranging new boulders. Over time this creates a shortage of raw materials.

4.2.4. *Water distribution*

Most of the sample check-dams do not follow strict rules for water allocation. Any mechanism to restrict water use by farmers would not be successful, as individual pumpsets are installed in the stream. However, water use efficiency is increased by the use of sprinklers and drip irrigation. Eighty-six percent of the sample farmers use sprinklers and/or drip irrigation.

Electric motors form the major power source (63%) for drawing water from the check-dams, while diesel and kerosene motors constitute 27% and 10%, respectively. In the past, when indigenous water lift irrigation systems using gravity flow were common, the beneficiaries were those who had their irrigated land at the downstream end of a check-dam. Motors have made it possible to lift water to greater heights, and those at upstream locations have now become beneficiaries.

Water allocation rules exist only in the case of check-dam I, in which four of the five farmers use a kerosene pump and they use temporary channels for water conveyance using gravity flow to their fields. Water is allocated on a rotational basis, somewhat similar to the *warabandi* system practiced in different parts of northwestern India (Maloney and Raju, 1994). Unlike *warabandi*, all farmers receive equal durations of turns, two and a half days. The farmers generally have agreed that farmers raising paddy are given priority when determining the allocations.

4.2.5. *Dug wells on streambeds*

The construction of check-dams in Kumbadaje panchayat has ensured the availability of irrigation water during summer. Water starts receding in the check-dams from the tail ends, thus reducing the temporal availability of water from check-dams to tail-enders. The tail-enders have found a solution in wells dug in the streambed. These wells are similar to the wells dug in beds of ponds during summer in Kathiawar in Gujarat state in western India (Agarwal and Narain, 1997).

Such dug-wells are either temporary or permanent. A permanent construction is closed with a concrete lid at the onset of the monsoon to avoid silting. The cost of digging a permanent dug well is about INR 20,000 whereas a temporary dug well can be dug for 10% of this cost. In 80% of the check-dams, farmers have dug many wells in the streambed. The largest number of dug wells (4) is possessed by one farmer in check-dam C, who owns the largest cultivated area (3 ha) in his/her group.

Conjunctive use of surface water and groundwater from dug wells has ensured extended water supply until the beginning of June when the monsoon starts. Further, impounding of water in the check-dams causes the water table to rise in nearby areas. Thus, those farmers who live outside the command area also benefit from check-dams. This might be considered a positive externality of check-dam development. Farmers report there is an increase in the water table up to a distance of three kilometres from a check-dam.

4.2.6. *Issues in the construction and management of check-dams*

As in other forms of collective action, the check-dams studied also face problems, classified below as technical and management issues.

4.2.6.1. *Technical issues*. The twentieth century witnessed a decline in construction of check-dams in Kumbadaje panchayat. The decline was rapid, up to the early 1930s, followed by a short period of increasing use until 1950, after which the declining trend continued. This historical trend in the construction of check-dams has been developed on the basis of interviews with elder residents of our study area.

Lately, construction of check-dams has suffered a setback due to increased groundwater exploitation through bore wells. Most of the farmers in our survey (29) use bore wells in addition to check-dams (Table 5). The government policy to promote bore wells as a source of irrigation has led to stagnation in the construction of check-dams. According to Balakrishna Rai, farmers with landholdings up to 2 ha are not required to pay electricity charges. Farmers with more than 2 ha pay a fixed fee that does not increase with the amount of electricity used. This serves as an incentive for groundwater exploitation using borewells. In addition some farmers use open wells (15) and ponds (18) to supplement their irrigation supply. This implies that increased demand for irrigation cannot be met from check-dams alone. Other factors contributing to the declining trend include the lack of skilled labour and the lack of cooperation among the farmers in a

Table 5 – Sample farmers using other irrigation sources in addition to check-dams

	A	B	C	D	E	F	G	H	I	J	Total
Number of farmers	5	4	4	13	4	16	6	5	5	4	66
Bore well	2	1	1	6	3	7	1	7	1	0	29
Open well	2	1	0	0	0	5	5	0	2	0	15
Pond	2	2	2	0	0	3	1	0	4	4	18

group. For example, check-dam A could not be constructed in 2001 and 2002, due to lack of cooperation among the farmers.

Other than the construction issues, the farmers have also raised concerns regarding the damage of check-dams. Check-dam construction, if not done by skilled labour, can fail by holes formed by crabs (*Portunus pelagicus*). Placing copper sulphate crystals in the holes can alleviate the problem. Constant supervision by those who reside nearby the check-dams is needed to prevent damage from crabs.

Special maintenance must be performed in emergencies. Such situations arise when check-dams located upstream are damaged and there is a rapid flow of water to check-dams located downstream. The emergency outlet in a check-dam must be opened immediately to divert the excess flow. In severe cases, downstream check-dams may fail and need to be reconstructed. For emergency maintenance work, all farmers contribute labour. In 2000, there was a collapse of all the sample check-dams due to heavy rains. This occurred because the collapse of one upstream check-dam was unnoticed by downstream farmers.

4.2.6.2. *Management issues*. Late building of check-dams, which creates conflicts between the beneficiaries of check-dams, is the major issue confronted in the management of check-dams. Construction of a check-dam generally begins at the beginning of December. However, there are a few groups, especially those at upstream locations, who begin constructing their check-dams late. Even if construction is late, enough water for local use can be stored in check-dams. However, if upstream check-dams are not constructed in time, water availability for downstream check-dams is greatly reduced. Even a short delay of one week can leave check-dams unfilled to maximum capacity.

Alternatively, check-dams downstream cannot be constructed in advance, as heavy flow in a stream makes it difficult to undertake construction. Downstream check-dams must bear more water pressure as water flow is increased due to the confluence of more tributaries when a stream reaches the farthest end. Timely construction of upstream check-dams is needed, as the streams are seasonal and water flow continues to the end of January in Kumbadaje. In short, late building often has a detrimental effect on tail-enders.

Furthermore, there are consequences if construction of all check-dams is not completed simultaneously. When water flow in a stream decreases, the outlet of a check-dam is closed. But the outlet of one check-dam can be closed only after closing that of the preceding check-dam on a stream. Close coordination is required among the heads of farmers' groups, yet such coordination is not always present. This leads to a decrease in water holding capacity of check-dams downstream, and a loss to farmers located downstream. The lack of coordination among heads of farmers' groups is a visible case of fragmented decision making.

The effects of free riding in check-dams are not as severe as those of late building. Free riders in this study are categorized as those outside the group (found in case of check-dams D, F and G), and those inside a group who draw water from a check-dam without contributing toward its construction and management. In 40% of the sample check-dams, there is visible free riding (outside and inside). In check-dam H, free riders are only those from inside the group. In this case, the head of the farmers' group is comparatively better off to bear the full construction cost of the check-dam. The average landholding of other farmers is about 2 ha. Considering substantial benefits from constructing the check-dam, the head of the farmers' group of this check-dam adopts a ''soft strategy'', as Sengupta (1991) has pointed out in a study on traditional irrigation in India and the Philippines.

Fig. 5 – An abandoned permanent check-dam due to technical failure while a temporary one constructed in front of it in the Kumbadaje panchayat.

4.2.7. *Role of government*

During the course of this study, we found that the government provided aid of INR 1000 per check-dam in 2003 through the panchayat. For such water harvesting systems, there are provisions to generate funds through government grants. Construction of semi-permanent and permanent check-dams is executed through panchayats under the Peoples' Planning Programme. In the case of check-dam F, the government supported construction of a concrete foundation; i.e., a semi-permanent check-dam. However, this effort failed as farmers needed to spend more money in the succeeding years for desilting the check-dam. The foundation was not properly designed and this has caused silting problems. We noticed also during the survey that one of the permanent check-dams constructed by the panchayat has been discarded by the farmers (Fig. 5). This is another illustration of the failure of check-dams constructed with government support. In this case, farmers have reverted back to construction of traditional check-dams, designed by farmers themselves, drawing on their experience. The farmers know how to construct check-dams that match the local topography.

5. Conclusions

Check-dams represent a traditional water harvesting system and play a vital role in sustaining and enhancing the agrarian life of Kumbadaje panchayat. This motivation, and more importantly the people's passion to carry forward traditional practices, are the major factors for community initiatives in building and managing the check-dams. Without check-dams, most of the agricultural land would remain unutilized during the summer, thereby limiting the scope for growing perennial (cash) crops.

Collective action among farmers is mostly noticeable during resource mobilization and construction of the check-dams. Cost-sharing arrangements vary among the check-dams in our study. The head of a farmers' group conducts most of the management activities of a check-dam on behalf of others. The success of this arrangement can be attributed to the homogenous and small size groups of farmers dependent on a check-dam. However, there is a lack of coordination among decision-makers belonging to different check-dams in the study area for timely and simultaneous construction of check-dams. Late building affects the usefulness and viability of check-dams. In most of the check-dams we studied, there is no definite and effective water distribution mechanism. However, with the increasing demand for water, farmers need to implement allocation mechanisms to avoid conflicts.

There seems to be some reduction in the importance of this traditional water harvesting system, as seen in the declining trend in construction of check-dams. The reason is not the lack of collective action among the farmers but the increased use of bore wells for meeting irrigation requirements. A decline in the availability of specialized skilled labourers for building check-dams may further contribute to this trend in the coming years. Subsidized electricity causes both over exploitation of ground water and excessive use of capital. Both contribute to the comparative neglect of check-dams. If the subsidy on electricity is not reduced, the government should consider providing appropriate incentives for constructing and managing check-dams, which enable more efficient use of water and also generate the positive externality of recharging ground water in surrounding areas.

Temporary check-dams are more suitable for water harvesting in our study area than semi-permanent and permanent check-dams. Many semi-permanent and permanent structures, built with government support, have become defunct due to defective construction. The traditional technology of building check-dams should be sustained in the study area. The role of the government should be limited to providing funds primarily for building traditional check-dams and emergency maintenance operations, with minimal intervention in the management activities of the farmers' groups. Such limited but critical government intervention is needed to sustain such traditional water harvesting systems in India and elsewhere.

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