SECURING WATER FOR FOOD

Naireeta Services Evaluation

Bhungroo Water Harvesting System in India

SEPTEMBER 2018

SECURING WATER FOR FOOD: A GRAND CHALLENGE FOR DEVELOPMENT

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ABSTRACT

The Bhungroo water harvesting system is an agricultural innovation that has received a monetary award and support from Securing Water for Food. The Bhungroo system helps smallholder farmers harvest rainwater throughout the monsoon season so they can use it during the dry season. The Bhungroo system was developed by Naireeta Services in the state of Gujarat, India, to tackle the issues of salinization, desertification, and water scarcity in the region.

This report details monitoring and evaluation of the recent installation of 52 Bhungroo systems among the poorest smallholder farmers of Harij in Gujarat's Patan district. From 62 interviews with Bhungroo owners in a stratified all-female sample, evaluators established a baseline using statistics on household incomes, crop yields, water practices, expenses, and perceptions and expectations of the Bhungroo system.

Though findings are preliminary, the women studied in this report appear to have fewer resources and to be more heavily impacted by regional water stress than a small nearby sample of women with established Bhungroos.

Aside from yield and income changes experienced as a result of using the Bhungroo system, the report suggests other important themes for further monitoring, including issues related to water sharing, irrigation practices and tools, and the climate and precipitation of the region. Water stress in the area appeared to be at an all-time high at the time of this study, while land degradation was unmistakably prominent.

The systems' owners expressed hope for the Bhungroo system, which presents a viable possibility for positive impact directly on their households and more broadly on soil restoration, food security, and female empowerment for the entire region.

I. INTRODUCTION

Many regions currently are suffering from increased drought and becoming more susceptible to land degradation and desertification. India, and particularly its westernmost state of Gujarat, has been heavily affected. It is in this region that Naireeta Services (Private Limited) developed the Bhungroo water harvesting system to tackle the interlinked issues of land degradation, water scarcity, agricultural irrigation practices, food security, and rural female empowerment.

Approximately 30 percent of India's total land area was experiencing degradation from 2011 to 2013[1]. The state of Gujarat included the third-largest area suffering desertification/land degradation, with over half of its land classified in these categories. Water stress in India has reached an all-time high: The 2018 Composite Water Management Index states that Indian groundwater is being depleted at unsustainable rates as drought increases.[2] Most areas of Gujarat are classified as experiencing high to extremely-high water stress. Though Gujarat is considered India's leading state in water management, seemingly out of necessity, the report also notes that it uses 88 percent of its water for irrigation.

Naireeta Services is a Securing Water for Food (SWFF) innovator, and its Bhungroo water harvesting system is the awarded innovation. Designed for rainwater conservation and irrigation innovation, the Bhungroo system consists of a pipe or pipes installed in the ground to filter, inject, and store excess precipitation from waterlogged fields, particularly during monsoons, in underground storage for use during dry periods.

Using excess rainwater during rainy seasons to irrigate in the dry season increases food security and lessens regional water stress. Furthermore, the Bhungroo system should aid in land restoration over time by renewing subsoil water supplies, thus decreasing soil salinity. Finally, the project promotes rural female empowerment since female farmers own the water rights under which the Bhungroo systems operate.

Each unit can drain five acres (two hectares) of land during the monsoon to provide 20 acres (eight hectares) of land with irrigation water during other seasons. Each farmer holds an average of three acres of land, which means each Bhungroo water-sharing group includes eight adjacent or nearby farms. These water sharing groups consist of female farmers who jointly hold legal rights to the Bhungroo-system-processed water. This female involvement is thought to lessen water sharing issues, and the groups, training, and legal ownership of water all are seen as potentially enhancing female empowerment.

1 Desertification and Land Degradation Atlas of India (Based on IRS AWiFS data of 2011-13 and 2003-05), Space Applications Centre, ISRO, Ahmedabad, India, 219 pages

2 NITI Aayog. Composite Water Management Index: A Tool for Water Management. June 2018. 177 pages.

The SWFF-Bhungroo study area represented by this report comprises 52 active Bhungroo systems spread across 10 villages in the district of Patan in northern Gujarat, with Harij being the nearest city. To begin monitoring and assessment of this area, all 52 currently functioning Bhungroo systems were visited and interviews of the farmers, selected from a random stratified sample across the 52 different groups, were conducted. This data should provide a strong baseline for tracking statistical changes resulting from use of the systems, particularly for crop yield and farming income.

II. BACKGROUND

In total, 62 interviews were conducted for the SWFF study area, which encompassed 10 villages in northern Gujarat. An additional six interviews took place in other areas where Bhungroo systems have been installed without SWFF support. Fifty-eight interviews were completed independently, including two double interviews. All interviews were conducted in the local village dialect of the Gujarati language with help from a translator (special thanks goes to the project's translator, Nirupa Jungi). The Fulcrum mobile application was used to store responses, and interviews also were recorded with a basic cell-phone voice recorder application.

The seasonal calendar for the Patan district of Gujarat is generally as follows:
July – September: monsoon
October – February: winter
March – June: summer

Average rainfall in Patan from 2013 to 2017 was 683 millimeters, with an average of 611 millimeters, or 90 percent, occurring during the monsoon.[3] Kumar, et al. (2014) used data from the India Meteorological Department to determine a Seasonality Index rating of 2.298 for Patan from 2002 to 2011, where a rating equal to or greater than 1.20 is considered extreme (with almost all rainfall occurring within one to two months).[4] Preliminary data shows 2018 was extremely dry, with a total monsoon precipitation of 173 millimeters, 28 percent of the annual average.[5]

Discussions in the region also indicated the year included the most severe drought on record, although it was said that the government was avoiding an emergency drought status announcement. However, meteorological projections estimate that precipitation in the region will increase, in part due to increasing temperatures caused by climate change, which also is expected to negatively affect crop yields.[6]

3 Customized Rainfall Information System (CRIS). Hydromet Division. India Meteorological Department. Gujarat, Patan. Retrieved from: http://hydro.imd.gov.in/hydrometweb/(S(w1qkpk45vjj4t2fqxid1gq55))/DistrictRaifall.aspx on October 28, 2018.

4 Kumar, V., et al. 2014. Decadal Comparison of Rainfall Seasonality Index in Gujarat. *Global Sustainability Transitions: Impacts and Innovations*. Retrieved from: http://www.krishisanskriti.org/vol_image/10Sep201506092936.pdf.

5 World Weather Online. Patan monthly climate averages. Retrieved from: https://www.worldweatheronline.com/patan-weather-averages/gujarat/in.aspx on October 28, 2018.

6 Patel, et al. 2015. Climate change and its impact on major crops in Gujarat. Journal of Agrometerology, 17(2):190-193.

1. GENDER

The interviewees were 100 percent female. As mentioned previously, this is because technically the innovation recipients were all females who had legal joint ownership of water rights associated with Bhungroo systems. However, men typically were present during the interviews and often provided answers as well. They particularly were likely to answer technical questions on topics such as harvest yields, income, and farm expenses. Men are almost always legal owners of the farmland, and some exploratory questions showed irrigation work in the area was either male-dominated or shared by females and males.

2. FARM SIZE

One of the first questions we asked to gain a sense of the village and population dynamics is that of the size of the household's farm or plot. Before leaving for the field it was noted that the local land unit is the bigah, which equals approximately 0.57 acre or 0.23 hectare. All respondents answered in terms of bigah, which was then converted.

TABLE 1. SIZE OF FARMS IN STUDY

	Bigahs	Acres	Hectares
Average	5.50	3.16	1.28
Median	4.00	2.29	0.93
Total	337.00	192.57	77.96

The average landholding size among the 62 interviewees is 1.28 hectares, whereas the median is slightly less than one hectare (0.93). In total, the 62 interviewees held approximately 78 hectares. Only two interviewees mentioned leasing part of their land, with another stating that at times she farms extra land on lease. Almost all interviewees said they own all of the land in question, with only one interviewee claiming to own none and instead being a laborer on her father-in-law's land.

Familial sharing of the farmland is common: 20 of the respondents, over 30 percent of them, responded "Yes" when asked if they shared land, in all cases saying they shared land within families, with children, parents, siblings, or in-laws.

3. FARMERS' WORK EXPERIENCE

Sixty-one of the 62 interviewees reported that their primary occupation was farming, with the only outlier responding "housewife." Fifty of those 61 interviewees answered a question about their average years of farming, indicating they could claim an average of 28 years, or a median of 30 years, as farmers. The interviewees who didn't respond to this question couldn't remember how long they had been farmers, or they answered qualitatively with a comment such as "since young."

4. OTHER OCCUPATIONS OR SOURCES OF INCOME

The interviewees were asked about additional occupations and forms of income, aside from from farming crops.

TABLE 2. FARMERS' OTHER OCCUPATIONS AND SOURCES OF INCOME

Occupation	Only day laborer	Only milk seller	Day laborer and milk seller	Other*	None
Total	13	20	16	3	10
Percentage	21%	32%	26%	5%	16%

All 62 respondents answered. For the respondents that answered "other", occupations are given below. One of these women was also additionally a day laborer, the second also owned buffalo, and the third had no further occupation.

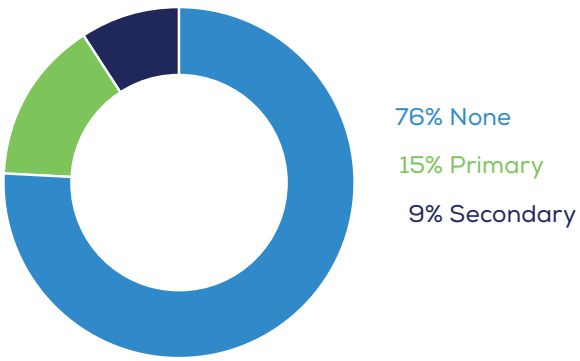
The two main secondary occupations or income sources for the female farmers were (1) working as day laborers and (2) selling milk from their own buffaloes and cows. Respectively, 47 percent of the interviewees perform day labor (either on other farms or in the city) and 60 percent sell milk from their own cows and/or buffalo. Three women also mentioned other jobs: owning a grain store, childcare, and managing a village well. Additionally, two women without additional occupations mentioned their husbands' occupations (as a hairdresser and a police officer). However this question was not asked directly, so the responses likely underrepresent husbands' primary or secondary occupations.

5. FAMILY SIZE AND EDUCATION LEVEL

With 60 responses, the mean family size was 6.3, and the median was six members. In total, 379 family members were represented within 60 families.

In regard to the female head of the house education level (which was the education level of the interviewees) there were 58 responses. Of these, 44 of the interviewees, or 76 percent, had no education. Nine women, or 15 percent, had finished between one and five grades in standard schooling (primary school), and five women, or nine percent, had finished between six and 12 grades in standard schooling (middle to secondary school).

FIGURE 1. EDUCATION LEVEL
n=60



III. METHODOLOGY

1. SAMPLE SELECTION

The questionnaire created for the SWFF-Bhungroo study included questions about livelihoods, crop yields, income, innovation and water use, time spent on agricultural activities, and problems with and suggestions for the innovation.

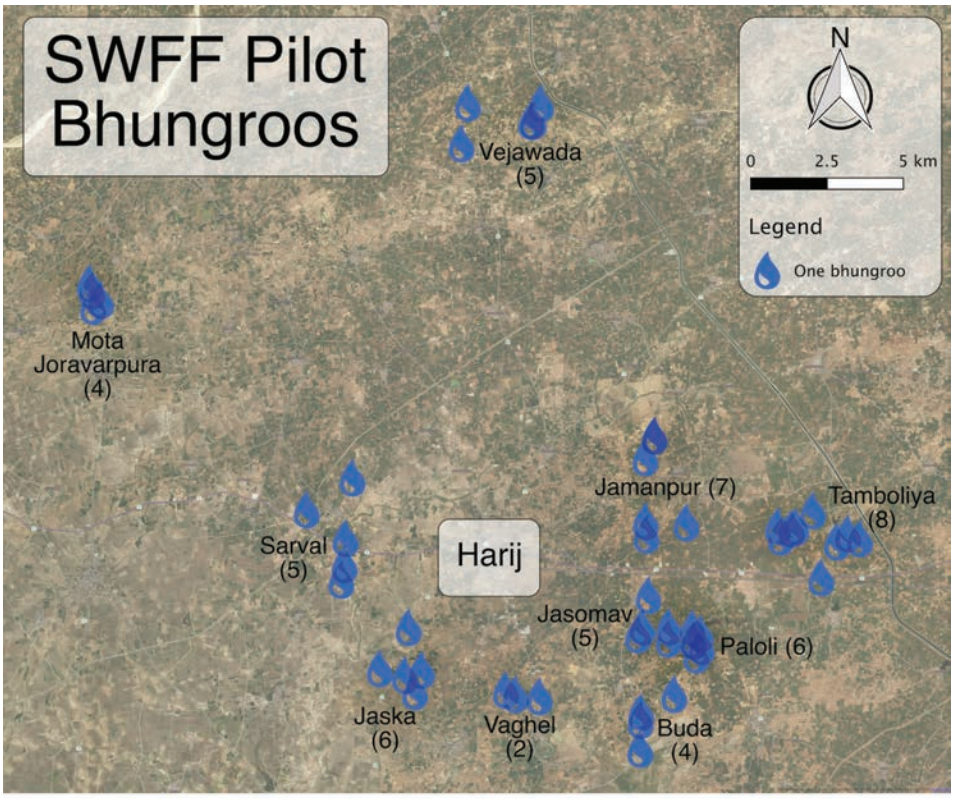
The Naireeta Services Ahmedabad office keeps a file on each of the original 54 SWFF Bhungroo systems. However, two systems were not installed, bringing the operational number down to 52 at the time of visit (July and August 2018). From these files, an Excel spreadsheet was compiled listing the 52 Bhungroo systems with names of the eight women belonging to each Bhungroo group, making a total of 416 active recipients. The files also included the local phone number of someone belonging to each Bhungroo group.

Primary interviews were selected through a random stratified sampling, created by selecting one of the eight women from each Bhungroo group by generating a random number of 1 through 8. Fifty-two interviewees were selected in this way. The Bhungroo systems and water are owned by all of the women in a group, but each system is physically installed on one farm (selected by surveying for the lowest geographical point within the eight farms). To avoid confusion, the farmer on the farm where each of the 52 Bhungroo systems were installed shall be referred to as "owner." From early on it could be seen from interviews with the randomly selected "owners" that they may have more specific knowledge in regards to the Bhungroo. As such, to gain further information, an additional 10 interviewees were selected by choosing one random Bhungroo "owner" from each of the 10 villages represented. As such, in total, 62 interviews were conducted, with 52 being primary interviews and 10 additional interviews.

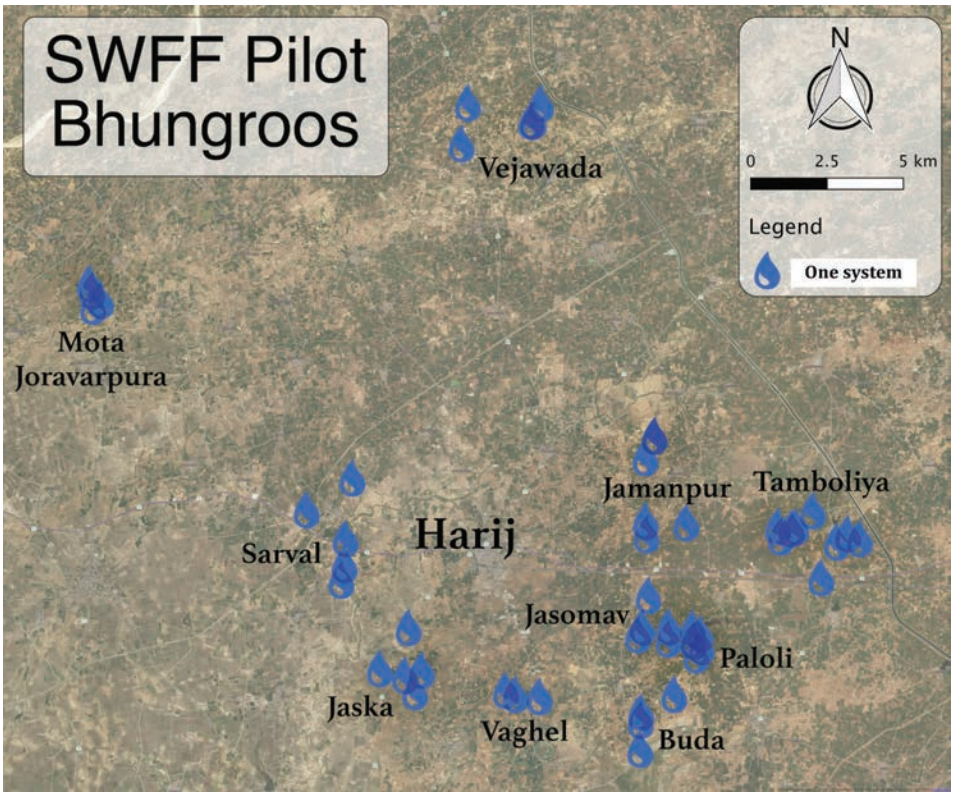
The 10 villages in the SWFF study area were Buda, Jamanpur, Jaska, Jasomav, Mota Joravarpura, Paloli, Sarval, Tamboliya, Vaghel, and Vejawada. As seen on the map, the number of Bhungroo systems in a village vary from two (Vaghel) to eight (Tamboliya). Once the interviewees were randomly selected, the contact number for each Bhungroo group was called and the interviews were set up.

At times, phones were switched off or numbers were incorrect, in which case other Bhungroo group phone numbers in the same village were used to communicate with the interviewees. The interviewees were located once the interviewers arrived in each village. Only three times were the selected women not available; a different woman was randomly selected from the same group. The individual Bhungroo systems were also visited for verification purposes and to update each one with GPS coordinates.

FIGURE 2. LOCATIONS OF HARIJ-PILOT SWFF BHUNGROO SYSTEMS



Map of the 52 operational Harij-Pilot SWFF Bhungroo systems. Created using QGIS. Each village is labeled, with the number of Bhungroo systems per village in parentheses.



IV. RESULTS AND DISCUSSION

The main issue encountered while administering the survey was the recent installation of the Bhungroo systems, which meant the interviewees had not actually used them by the time of interviews. The majority of the systems were installed two to three months prior to the visit, during the dry season. Also, the monsoon rains were late, with only one small monsoon rain occurring before the end of July and the field visits. Because of this, the systems had little water stored within them and almost no possibility for prior use. As such, baseline data is presented below with discussion instead of change metrics.

The general perspective of interviewees about the Bhungroo systems at the time of the interviews was uncertainty. Because there had not yet been a monsoon, the systems had not started functioning and interviewees were uncertain as to how and whether they would work. However, a majority of interviewees still made positive comments about the systems, stating that they were happy to have received one, hoped it would work, and wanted more for their village.

1. BENEFITS

Because the Bhungroo systems were not yet in use at time of the survey, the women were asked whether they expected to gain benefits from the installed systems. When asked further about the type of benefits, they mentioned only water, or more specifically "good" (not salty) water. Responses were as follows:

TABLE 3. FARMERS EXPECTING BENEFITS FROM THE BHUNGROO SYSTEM

Expects Bhungroo benefits?	Number of answers	Percentage of total interviewed
Yes	36	66%
Not sure	9	17%
No	9	17%
Number of respondents	54	100%

Of those who answered "not sure" or "no", six were concerned the water would be salty and/or the depth of the Bhungroo storage would be too deep. When told that the water should become less salty with the monsoon, many interviewees seemed skeptical. As described by the Naireeta Services team, a greater amount of water entering the Bhungroo from the monsoon would dilute the salt present from the soil, obtaining a level suitable for crops (and even drinking water). One mentioned that a different Bhungroo system of 200 feet in depth in Sarval never gave fresh water. Two women said their farms are too far away to use the Bhungroo system, and one of these women mentioned she

had her own system. One woman was aware there would be benefits only if the monsoon rains came. Five women voiced uncertainty about water sharing from the Bhungroo system. Two women said they believed if there wasn't sufficient water, the neighbors wouldn't share, while another two weren't aware that they were in water sharing contracts.

It is worth noting that one Bhungroo system was found to be functional after a short rain on the last day of field visits. The family was very excited to announce that the water was not salty and they had already started irrigating their field.

2. CROP YIELD/SURVIVAL

The tables below are mostly for crops grown in 2018 during the monsoon and harvested in winter. Because of weather changes and the monsoon still having not appeared, many planted crops were in danger of being lost.

It should be noted that the farmers were planting hardier, more weather-resistant crops such as castor, millet, and wheat. The millet, however, did not seem to perform well, with 36 percent of it a total loss. Cumin is a cash crop for the region; however, the majority of farmers in the study had not ventured to plant it, and the two who did lost their entire crop.

TABLE 4. FARMERS' CROPS, HARVESTS AND LOSSES

	Castor	Millet	Wheat	Lentils	Mung	Cumin	Mustard	Cotton	Guar beans	Grass*
Number of interviewees growing	36	11	11	5	3	2	1	1	1	4
Total kilos harvested	55,352	13,250	17,356	2,594	1,120	0	261	746	224	2798
Average	1,538	1,205	1,578	519	373	0	261	746	224	700
Median	1,120	933	1,120	280	373	0	261	746	224	537
Number of losses	2	4	0	0	0	2	0	0	0	–
Percent loss	6%	36%	0%	0%	0%	100%	0%	0%	0%	–

Crop yields in kilograms, calculated from given amounts in maund, the local weight unit, see Appendix B
1 maund = 37.3242 kilograms. See Appendix B for tables of amounts in maund and pounds.
** These are numbers of farmers who grow grass to sell, not just for their own livestock use. These values include estimates from farmers currently growing grass, whereas all other crop values are from previous harvests. Grass values are highly estimated, as farmers collect the grass in packets or baskets, then converted roughly to kilograms. Grass, including why losses are excluded, is further explained below.*

FIGURE 3. CROP OUTCOMES OF INTERVIEWED FARMERS, BY CROP TYPE

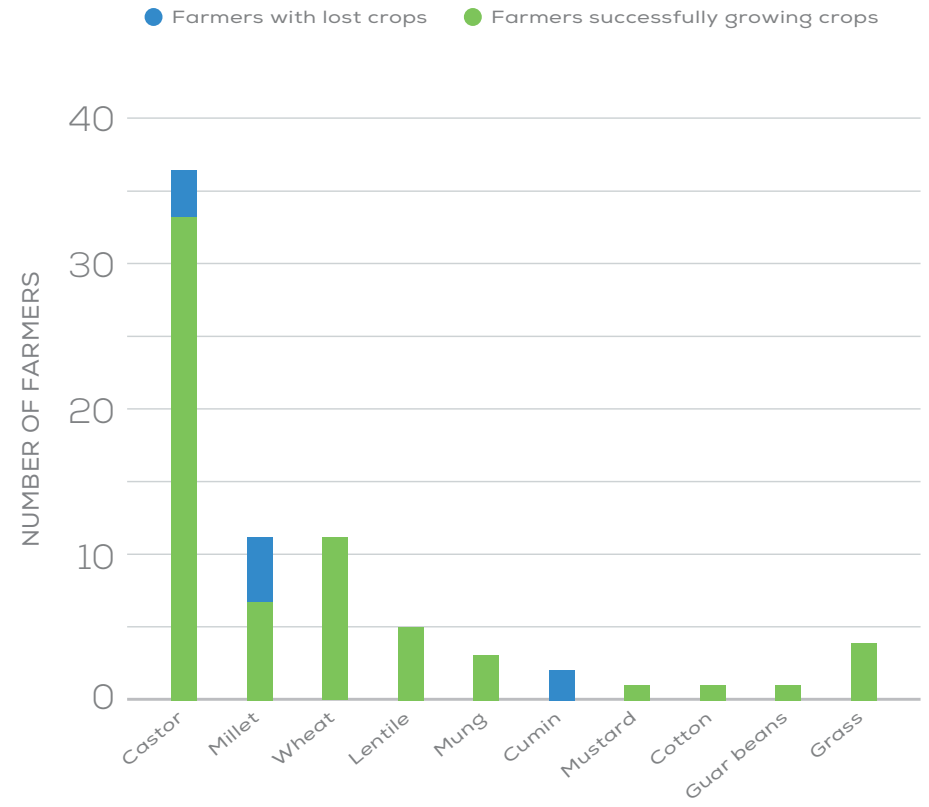
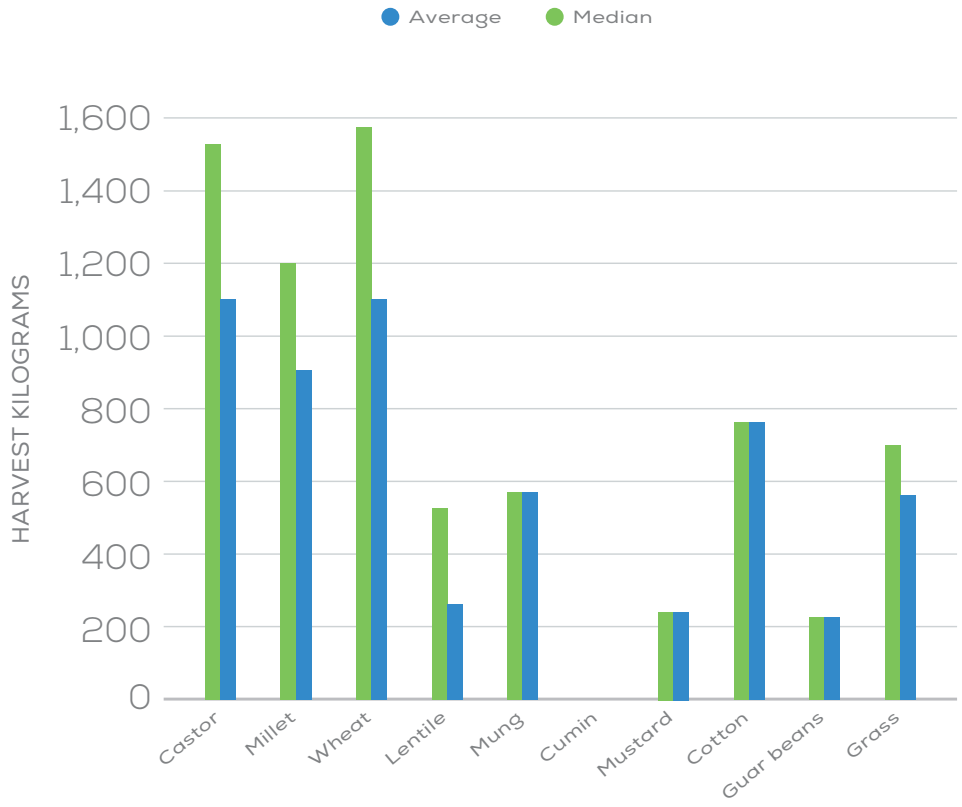


FIGURE 4. AVERAGE AND MEDIAN CROP YEILDS



Grass/pasture is another crop grown by the farmers interviewed; 10 interviewees said they grew it previously and 17 mentioned growing it currently. Grass usually is grown to feed a household's livestock and not harvested. However, four interviewees did mention harvest data, and a very rough estimate can be ascertained from this, provided in the table above. Though not for sale, two women mentioned not having enough grass to feed their livestock. These statistics could be considered as losses under a certain perspective, but are not included as the amount of loss is unquantified.

Also of note: 100 percent of the interviewees responded "Yes" to a question asking if they had used synthetic pesticides. However, translation may be an issue in this case; interviewers did not ask the exact type of pesticides used, so it is possible that some organic pesticides were used. At one point, interviewers asked what pesticide brands were used; farmers often were not sure of the names, but Monocoto and Basali were both mentioned. It is possible that Monocoto is the local name for Monocrotophos, an organophosphate insecticide. Basali was said to be used for cumin, though it is uncertain what pesticide this refers to specifically.

3. HOUSEHOLD USE OF CROPS

There was a distinct division among interviewees in their household use of crops. Castor and cotton, as well as cumin and mustard, were grown almost exclusively for the market. However, crops such as millet and wheat were almost exclusively for consumption by the farmers' households, unless they happened to have a larger harvest and a surplus to sell. The farmers grew lentils, guar, and mung mostly for selling, though sometimes they kept small amounts for the household. Grass typically was used by households for their own livestock, but a few interviewees sold it as food for others' livestock. Sharing harvested crops was an uncommon practice, with only two mentioning doing so; one **additional** interviewee mentioned giving some of the harvest to farmworkers.

4. FARMING AND NON-FARMING INCOME

One set of questions asked the farmers about both their income received from farming and from other occupations. In total, 61 interviewees reported roughly 1.3 million rupees of income from the last farming season. At the current rate of 1 rupee to 0.014 USD$, that is slightly more than $18,000 in total annual income amongst all 61 farmers.

TABLE 5. FARMERS EXPECTING BENEFITS FROM THE BHUNGROO SYSTEM

Farming income	Rupees	Dollars
Total	1,290,200	18,062
Average	21,151	296
Median	12,500	175
Number of interviewees with no farming income	17	
Percentage of interviewees with no farming income	28	
Number of respondents	61	

The average income per farmer was roughly 21,000 rupees, or almost $300. However, the median income was roughly half of this at 12,500 rupees, or $175, which shows the effect of a few high-earning outlier farmers. Seventeen interviewees, or 28 percent, reported a farming income of zero because they either experienced complete crop losses or did not have excess harvest to sell.

TABLE 6. ANNUAL NONFARMING INCOME BY TYPE OF WORK, 2018

	Milk		Day labor		Other		Total, all types	
	Rupees	Dollars	Rupees	Dollars	Rupees	Dollars	Rupees	Dollars
Total by type	2,256,02	31,584	266,100	3,725	142,00	1,988	2,664,129	37,298
Average	70,501	987	12,671	177	71,000	994	57,916	811
Median	50,714	710	8,400	118	71,000	994	39,600	554
Losses	6							
Number of respondents	32		21		2		46	

The most common additional income came from selling the milk of cows or buffalo. Of 37 total respondents who owned buffalo/cow, 32 gave income estimates for milk. The average annual milk income was $987, with a median of $710. The women typically reported income from selling milk as a payment every 10 days, though sometimes weekly, reflecting the payment scheduling of local milk cooperatives. These amounts were extrapolated to arrive at an annual income, so the average is a very rough estimate. Six women reported not having recent milk income, either because their livestock produced no milk or they did not have enough to sell.

Thirty women reported working as day laborers; 21 gave usable income estimates. The average annual day laborer income was $177, with a median of $118. Typically, the women reported a daily wage, or a range of daily wages, and then were asked to estimate how many months they worked in a year. Assuming, in most cases, six days per week of work during these months, this data was then extrapolated to find a rough estimate of annual income.

Three women reported other livelihoods: selling grain, managing a village well, or childcare. Of those three, two reported incomes (selling grain and managing the village well). These were calculated with other non-farm incomes, which resulted in an average annual income for 46 respondents of $811, with a median of $554. This divergence again shows a few interviewees were significantly more prosperous farmers.

5. EXPECTATIONS OF CROPS AND INCOME USE

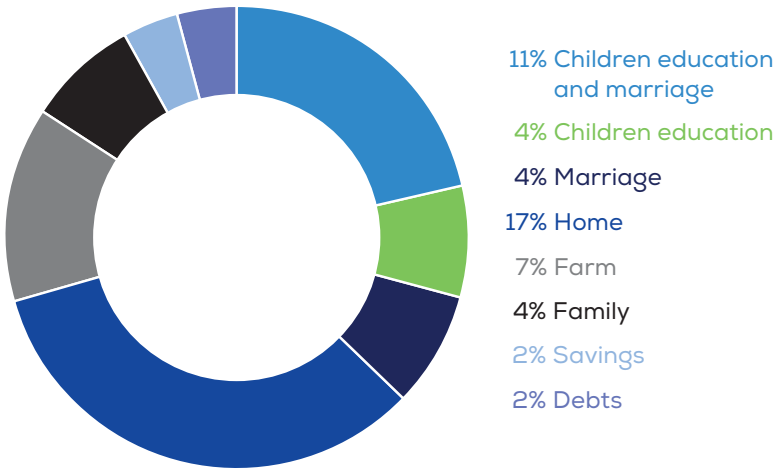
Thirty-four of the interviewees said they would grow more and/or new crops if they could obtain more water from the use of the Bhungroo system. They often mentioned the extra crops grown would be used for both their households and selling.

Interviewees were asked how they would spend extra income from the use of the Bhungroo system. Thirty-two respondents answered one or more of the following:

Nearly half of the respondents said they would spend extra income on improvements to the home or farm, whereas over a third of the interviewees mentioned the education and/or marriage of children.

FIGURE 3. CROP OUTCOMES OF INTERVIEWED FARMERS, BY CROP TYPE

n=34



6. TIME SPENT ON AGRICULTURE AND EXPECTATIONS

The 35 respondents who answered a question about time spent indicated they spent on average 7 1/2 hours a day on agricultural activities, with a median of eight hours. Forty-four women stated that if they were to receive more water from the Bhungroo system they would spend more time on agricultural activities. However, this data is not reliable due to unanswered questions such as who performs irrigation work on the farms and how much time they normally spend on this work. A focus group or follow-up discussion could help interviewers better understand the implications of these answers.

7. AFFORDABILITY

The farmers were asked about how much money they had spent, or invested, in the installation or maintenance of the Bhungroo system, with responses as shown below.

TABLE 7. OWNER INVESTMENT IN A BHUNGROO SYSTEM

Bhungroo investment	Rupees	Dollars
Total	179,500	18,062
Mean	3,042	296
Median	0	175
Interviewees reporting zero investment	42	
Maximum	65,000	910
Number of respondents	59	

Fifty-nine responses indicated an average investment of about 3,000 rupees or $42; however, the median shows that this is skewed toward a few large investments in Bhungroo systems. The median investment was 0, with 42 of the 59 respondents (71 percent) stating they had invested nothing in the system. The highest investment was 65,000 rupees or $910, this amount included buying a diesel pump for use with the system, which cost 40,000 rupees, or roughly $560.

8. WATER PRACTICES

The sources of irrigation water noted from 60 interviewees included rain, surface water (pond or lake), ground (borewell), and commercial purchase. Forty-nine of the respondents mentioned using rainwater, with 15 interviewees, or 25 percent, having access only to rainwater. Rain water was always the primary source whenever it was listed; it is possibly under-represented as farmers may not have considered even needing to mention it. The most common response given by farmers was utilizing both rain and surface water, with 26 respondents, or 43 percent, falling into this category.

FIGURE 6. IRRIGATION SOURCES

n=60

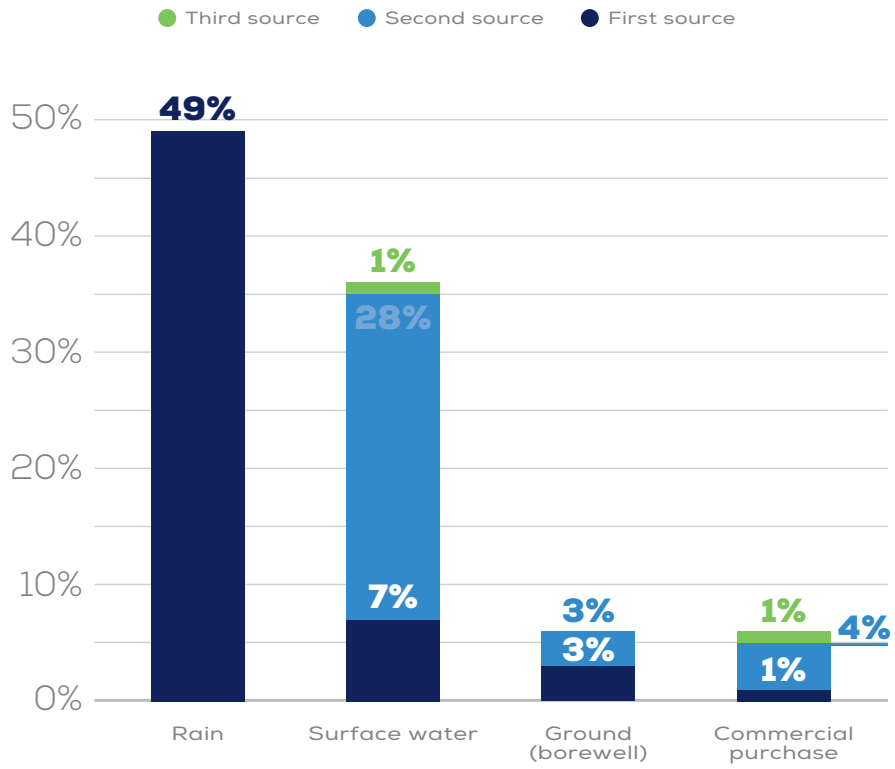


Figure 6 gives the total number of respondents that answered to having one of the above four irrigation sources. First, second, and third source refer to how many farmers listed this source as the first, or primary, source of irrigation water, the secondary source of water, or the third source of water (typically an afterthought/of infrequent use).

Additionally, almost 42 percent of respondents had access to only one source of water, 55 percent to two sources, and only 3 percent to three sources.

The two methods of irrigation in the region are rain and flooding. Sixteen of 59 respondents said they use only rainfed irrigation; the rest said they rely on flood irrigation as well, typically using diesel pumps.

9. WATER EXPENSES

The interviewees were asked about how much money they spend annually on water expenses.

TABLE 8. ANNUAL WATER EXPENSES

Water expenses	Rupees	Dollars
Total	988,350	13,837
Average	24,709	346
Median	16,500	231
Number of respondents	40	

Forty respondents reported spending a total of 988,000 rupees or about $13,800 on water expenses annually. The average annual expenditure was $346 and the median $231. Instead of giving a direct amount, 10 of the respondents answered that they will use one-third of their harvest to pay for water, a common practice in the region. The last farming income given or calculated from given information was used to create a dollar estimate for these responses. However, it should be noted that the practice of promising one-third of a harvest could have negative consequences; farmers who don't have an adequate harvest could go into debt or lose some of their land.

10. PERCEPTION OF WATER PROVISION

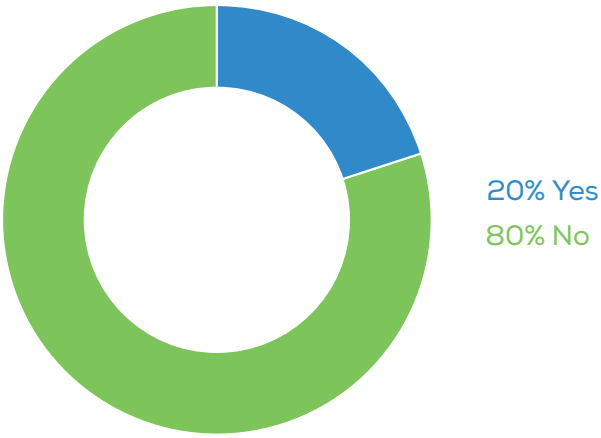
An exploratory question asked whether the Bhungroo system would provide enough water for the farmers. Since the system hadn't been used, and especially not for varied seasons, this couldn't be known from experience. Instead, the amount of water was estimated that each individual interviewee's farm would need going forward. This was calculated by first estimating that the Bhungroo system has an average storage potential of 167,000 liters, then dividing by total bigahs in all eight farms in a Bhungroo water sharing group to arrive at the amount of water that should be provided per unit of land area. This per-bigah amount was multiplied by the size of each interviewee's farm to estimate annual water needs.

The interviewees were asked if this amount of water would be enough for their needs. The responses are noted below; however, many of the farmers were unsure and could not respond.

Forty-six farmers did respond, and the majority of them believed that the estimated water provision amount was too low for their needs. This could be partly because the reported farm size from the innovator often was lower than the farm size the interviewees gave, as discussed in section 14. But it may also indicate that the calculations are off or that a Bhungroo system is not capable of providing all the water needed for its entire allocated area.

FIGURE 7. SUFFICIENCY OF ANNUAL ESTIMATED WATER PROVISION

n=46



11. OTHER FARM EXPENSES

TABLE 8. ANNUAL WATER EXPENSES

Annual farm expenses	Rupees	Dollars
Average	28,254	396
Median	22,500	315
Total	1,667,000	23,338
Number of respondents	59	

Other farm expenses (seeds, fertilizers, pesticides, etc.) amount to an annual average of roughly 28,200 rupees, or almost $400, per farmer. The median is slightly lower at $315. The total for 59 respondents comes to approximately $23,300.

12. FINANCE SOURCES FOR FARM EXPENSES

When interviewees were asked how they financed their agricultural activities, the vast majority responded that either "through my own savings" (43) and/or "by village money-lenders" (39) were the only or one primary source of finance. Only three interviewees cited bank loans, and just one said government subsidies. As for the number of finance sources, 33 respondents, or 56 percent, reported only one finance source.

TABLE 10. FUNDING SOURCES FOR AGRICULTURAL ACTIVITIES

Funding sources	Number of responses	Percentage
Own savings	18	31%
Village moneylenders	15	25%
Own savings and village moneylenders	22	37%
Own savings and private bank loans	2	3%
Village moneylenders, state bank loans, private bank loans	1	2%
Own savings, village moneylenders, government subsidies	1	2%
Number of respondents	59	100%

13. IMPACT ON POVERTY

In this study, Innovations for Poverty Action's (IPA) Poverty Probability Index (PPI) for India 2011 was used to attempt to unobtrusively gain an understanding of the households' poverty levels. Interviewers asked about the "number of household members" and "general education level of the female head," in this case the interviewee. Interviewers also noted whether each household owned certain items, such as a refrigerator, a television, an electric fan, furniture, or a vehicle.

This is a very uncertain estimation, of course, and it was made more uncertain because interviews typically were not conducted inside the home. Even at interviewees' homes, families usually set up a space for the interview in the yard. For that reason, it was difficult to know whether the household possessed certain items or not.

The data from 60 interviews yielded an average PPI score of 14, with a median of 11. According to IPA's PPI source for the International 2011 (Purchasing Power Parity) PPP Lines, this translates to an 18.3 percent likelihood the interviewees were in the $1.90/day category, a 75.2 percent likelihood they were in the $3.10/day category, a 90 percent likelihood they were in the $3.80/day category, and a 92.3 percent likelihood they were in the $4/day category.

14. COMPARISON OF LATEST INNOVATOR M&E STATISTICS WITH LATEST SWFF M&E STATISTICS

The only data that could be used to compare statistics gathered in this report with innovator-reported statistics is farm size, due to the unavailability of other innovator statistics.

TABLE 11. FARM SIZE

Farm units	M&E Bigahs	Innovator Bigahs	M&E Acres	Innovator Acres
Average	5.5	4.1	3.2	2.3
Median	4	4	2.3	2.3
Total	337	257	193	145

As we can see in Table 11, the median farm size of interviewees for this report was the same as median farm size reported by the innovator. The innovator's reported farm-size average and total landholdings data, however, are roughly 24 percent less. The way familial lands were divided and regarded could account at least partially for this. Specifically, large landholdings reported by an interviewee likely were divided among various family members by the innovator during surveying and accounting.

15. PROBLEMS AND SUGGESTIONS

Interviewers asked the farmers whether there were any problems with the Bhungroo systems or any suggestions for improvement. Problems and suggestions can be divided as follows:

TABLE 12. PROBLEMS AND SUGGESTIONS CATEGORIES

Electricity	Depth	Salty water	Pump	Pipe size	Cost
21	15	11	5	2	1

The number one suggestion for Bhungroo system improvement related to electricity provision. Many of the interviewees mentioned that their farms did not have electricity. Diesel pumps are a common means of irrigation in the region; however, they are quite costly to run, as indicated in the water expenses section, so farmers would like electricity to be provided. Eight interviewees even mentioned wanting solar electricity. Naireeta Services said it already had contacted the local electricity companies to provide hookups to the farms with Bhungroo systems, and it is planning to take the farmers soon to apply for electricity provision. A related suggestion involves the pump; many of the Bhungroo systems have no irrigation pump, electrical or diesel, and a few farmers mentioned they would like these to be provided.

Two interrelated problems are depth and salty water. Many of the systems had only salty water in them at the time of the visit. However, Naireeta Services stated that once more monsoon rains came, the salinity of the water would decrease. Sometimes interviewees did not seem to believe it, and many believed the water was salty because the systems were not deep enough. However, the depths they wanted for their Bhungroo systems would be more akin to the depths of borewells which access the region's freshwater reservoir. It is currently illegal to use reservoir water for irrigation, as it needs to be preserved for drinking water. Further assessments need to be completed before these two problems can be resolved. Of note, two interviewees mentioned their Bhungroo systems actually were too deep (Bhungroo systems No. 14 and No. 47).

Two interviewees mentioned pipe size was an issue. One said the pipe was not long enough; it was only six feet and it should have been eight feet. The other believed pipe diameter was not large enough and the pipe would be difficult to connect to a pump (Bhungroo systems No. 25 and No. 41). One interviewee mentioned cost as an issue, though it is possible she was speaking about her general water expenses (one-third of her crops) rather than the amount she spent on the Bhungroo system (2,000 rupees). Finally, one system was broken at the time of visit (Bhungroo system No. 27). The farmers stated that the pipe was not fitted properly and had filled with clay. Naireeta Services said, however, that the farmer had dumped the dug-out soil from the installation into the pipe, and for that reason it requested some payment for the repair.

16. KNOWLEDGE OF AND INTRODUCTION TO NAIREETA SERVICES

Of 57 responses, 12 (21 percent) indicated the interviewees both knew how the Bhungroo system works and had shared this knowledge with others, whereas 45 either did not know how the system works or had not shared this knowledge with others (79 percent). Fifty-seven interviewees provided information on how they had heard about Naireeta Services, whereas the remaining women were unsure. The most common means was through neighbors. The number of responses for each introductory information source is given below.

TABLE 13. SOURCES OF INTRODUCTION TO NAIREETA SERVICES

Harij office	Neighbor	Community visit	Family	Village head	Advertisement
13	32	12	4	2	2

17. BENEFITS FROM NON-SWFF-BHUNGROO-SYSTEM COMMUNITIES

In addition to villages in the area covered by the SWFF study, two other villages were visited that had previously installed Bhungroo systems: Sajupura and Dhadhana. Only six interviews were conducted, with five in Dhadhana and a large discussion in Sajupura. Because of the low number of data points, no statistical comparison between the datasets can be made. However, general insights from the non-SWFF-study communities will be discussed here.

Interviewees appeared to be comparable in demographics to SWFF-study interviewees. They had farmed a similar number of years, sold milk, held day laborer jobs, and managed farms of comparable size (on average owning 5.4 bigahs, the same as SWFF interviewees). In general, they also grew the same crops, though sorghum and fennel were noted for the first time.

Sajupura ended up being a special case; only one interview was conducted and it became apparent that a discussion was required. Halfway through the interview, the interviewee noted she had stopped using her Bhungroo system long before. Furthermore, no one in the village was still using their Naireeta-Services-provided Bhungroo systems. The systems had been installed eight to 10 years previously and they worked well for a couple of years. However, the government then opened a canal and everyone switched to using canal water. The Bhungroo systems sat unused for years and filled at least partially with clay. Two years ago, the canal was closed and when the farmers tried to use their systems again, they didn't work or worked very poorly.

From the story about systems in Sajupura, it can be gathered that the Bhungroo systems require some use or maintenance to continue functioning. Farmers who choose to switch to another water source may not be aware of this issue. A positive reflection on the Bhungroo system is the story one

farmer told. After the canal closed, he built his own Bhungroo system using the same design and depth as the original one installed by Naireeta Services. This farmer said that when the monsoon comes, his Bhungroo-produced water is good (i.e., not salty) and provides sufficient irrigation for his crops. Villagers were asked if they would want their Bhungroo systems to be repaired, or otherwise have new Bhungroos installed. There was a strong positive consensus among the farmers that they want the Bhungroos repaired or re-installed.

In the case of Dhadhana, the village presented a very positive story of the Bhungroo systems' results. The systems of the five women interviewed had been installed anywhere from two to three years previously to 10 to 12 years previously. The women stated that, as long as the monsoon came, they had enough water for irrigation from their Bhungroo systems, their crops grew and survived better than before, and they would invest in maintenance of the systems in the future. One woman said she could grow more water-reliant, more marketable crops, such as cotton and cumin, after the Bhungroo system's installation.

Before the Bhungroo systems were installed, seasonal yields for the non-SWFF-study farmers' crops, such as cotton, guar, millet, wheat, and castor, were very similar to those in the SWFF study area – roughly 10 to 20 maund, depending on the crop. After the Bhungroo system installations, the farmers reported that their yields increased to 30 to 60 maund annually, and they estimated their farming incomes increased to double or triple what had been before using the Bhungroo systems. All of the women stated that they spent the extra income on home expenses; one said she spent the extra money on farm expenses as well. One woman answered that she spends the same amount of time farming now, whereas the rest said they spent more time farming after the Bhungroo system installations. One woman mentioned working less as a day laborer after the Bhungroo system installation.

All of the interviewees stated that they have no problems with their Bhungroo systems. As for suggested improvements, one woman said she wanted an electric pump (she was using diesel fuel). Another farmer (a non-"owner") replied that she wanted her own Bhungroo system, so she would not have to wait her turn for water. The women still are paying for water because they all are using diesel pumps, on average spending 47,500 rupees or $665 annually. However, before installation of the Bhungroo systems, they did not have enough water available, sometimes none, and they could not take care of their crops.

The women have been very positively affected by having the Bhungroo systems. In fact, both the interviewees and groups in the surrounding areas were insistent that more of the villagers, or rather everyone in the village, should be provided with a Bhungroo system.

V. CONCLUSION

Unfortunately, due to the delayed installation of the Bhungroo systems, this report could not provide a proper one-year evaluation. Instead, it provides a strong foundation with baseline data for the SWFF study area that can be used to track changes going forward. The Bhungroo systems, which were all installed from May to June 2018, were only one to three months old by the time of the field visit. However, some preliminary insights emerged from the SWFF study area interviews, as well as visits to non-SWFF-study areas that had older systems.

It may be useful to pay attention to a few of these insights in future monitoring. First, group water sharing should be reviewed, as it is important to monitor whether or not the sharing arrangements are successful and to ensure no parties are left behind. Second, questions as to who is performing irrigation and how much time they spend using it could provide more insight into the innovation's impact.

The innovator should consider promoting electrical connection and pumps among the Bhungroo system owners. Diesel pumps seem to be unsustainable because they are expensive for the farmers and lead to further issues of ownership.

Finally, the innovator and farmers should monitor the climate of the region. As noted in the Background section, projections show rising precipitation levels but also rising temperatures, with a direct negative impact expected on crop yields. Bhungroo systems may be able to relieve some of this stress, but increasing temperatures and flooding likely will remain issues.

The SWFF study area contained 416 women across the 52 Bhungroo water-sharing groups. With an average household of six members, this could account for roughly 2,500 villagers across 10 villages who have a connection to a Bhungroo system.

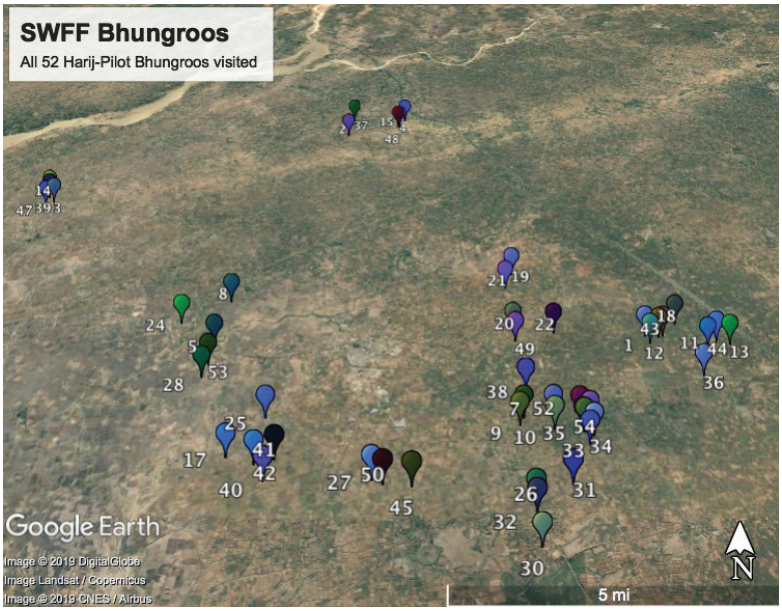
Though they were not yet able to use the Bhungroo systems, the majority of interviewees were optimistic about seeing future benefits from them. Farmers in the region already have improved their yields by planting hardier crops better suited for arid climates, but water stress issues still are noticeably prevalent. Low crop yields and entire crop losses have become common in recent years, and relying on uncertain water provision from the state is risky.

For these reasons, local solutions such as the Bhungroo water pipe and storage system have a greater chance of impacting the poorest farmers while also providing additional benefits including female empowerment.

VI. APPENDICES

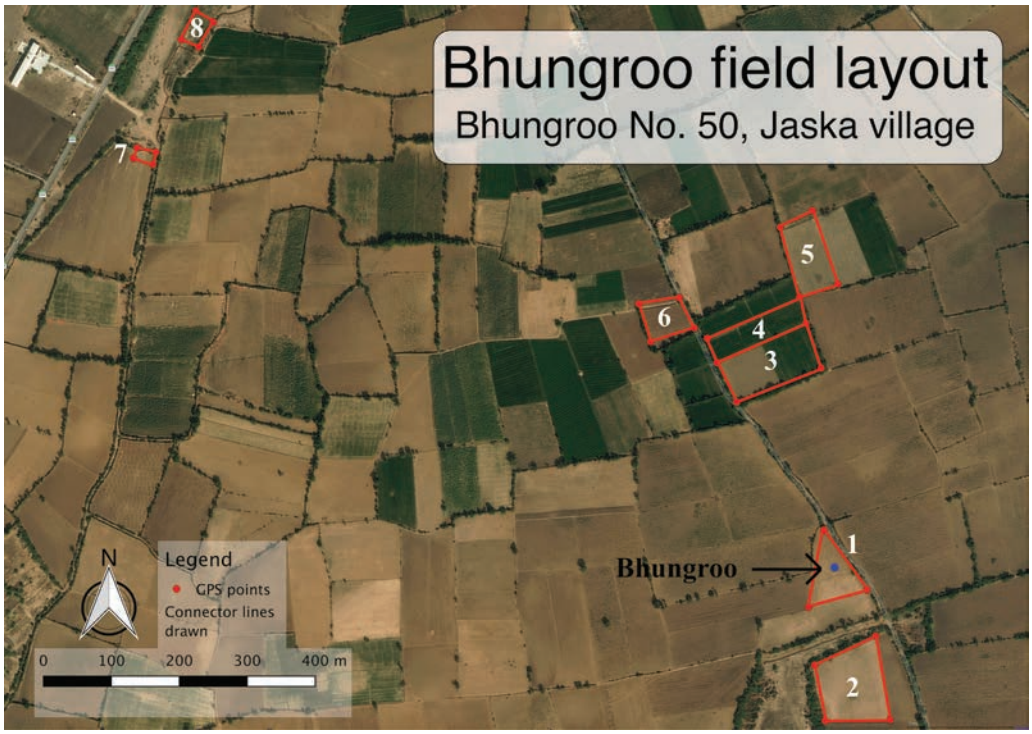
1. ADDITIONAL MAPS

FIGURE 8. MAP OF BHUNGROO SYSTEMS IN THE SWFF STUDY AREA, BY SYSTEM NUMBER



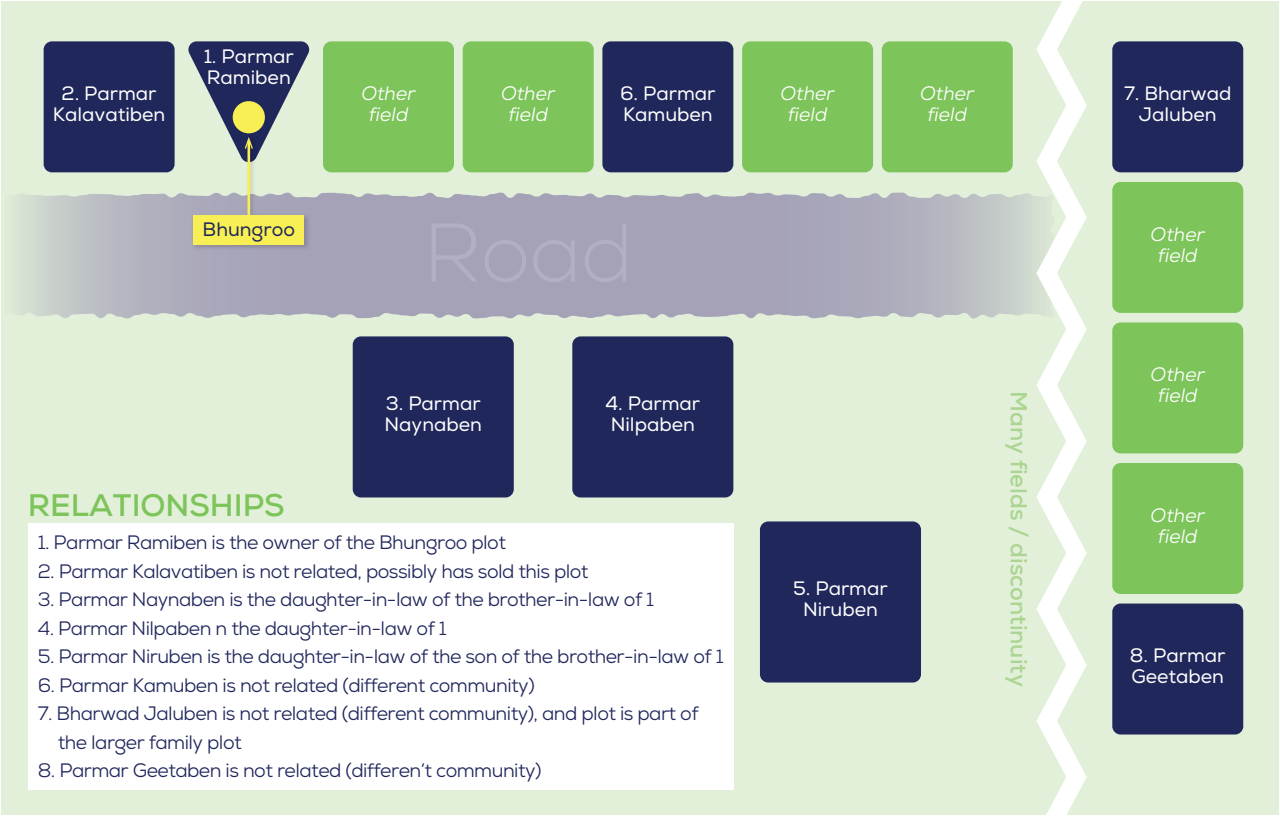
SWFF Harij-Pilot Bhungroo system map. Each system is labeled by a given identification number. Made with Google Earth Pro.

FIGURE 9. BHUNGROO FIELD LAYOUT EXAMPLE, JASKA VILLAGE, SYSTEM NO. 50



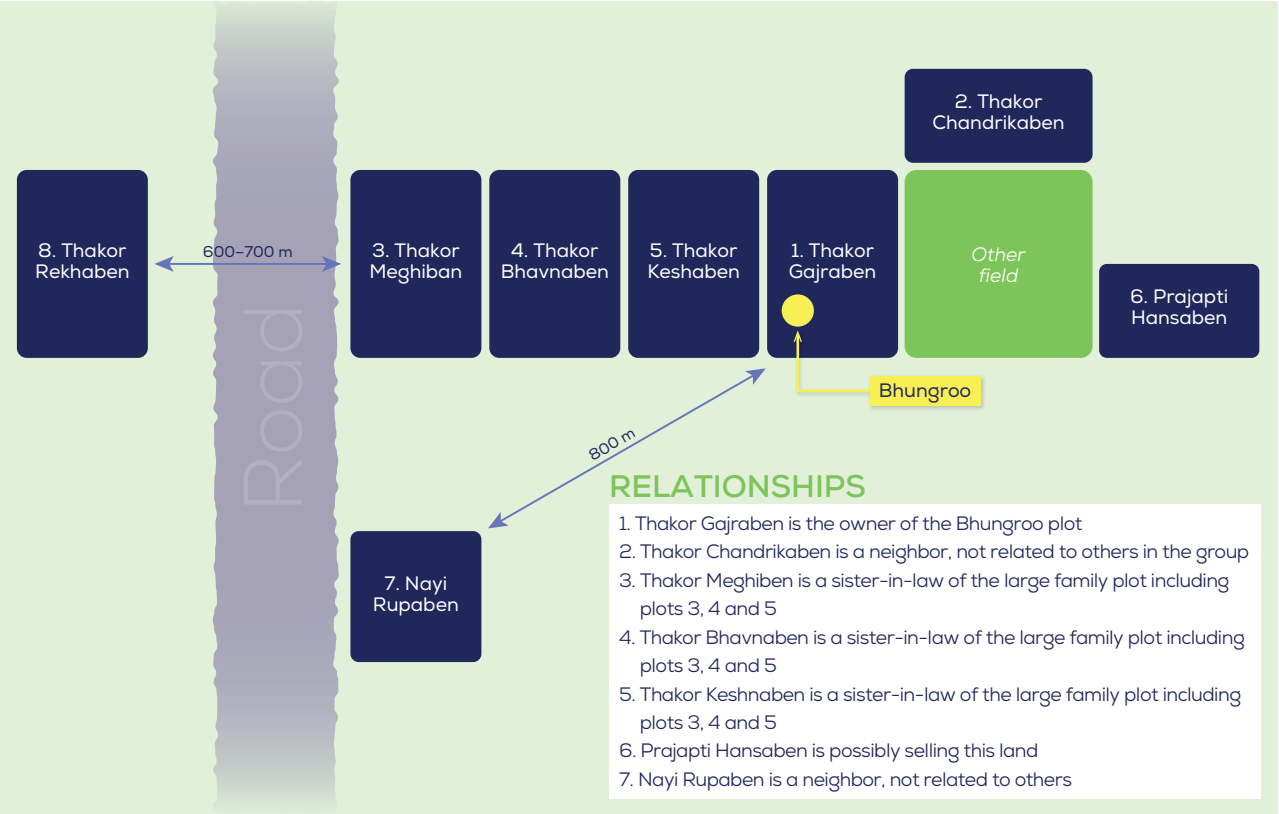
An example of field layout in a Bhungroo system water-sharing group. Outlined fields are managed by farmers in the water-sharing group for Bhungroo system No. 50. They are numbered 1 through 8 in order of proximity to the Bhungroo system. Made in QGIS with GPS points taken in-field.

FIGURE 10. MAP OF PLOTS BELONGING TO BHUNGROO NO. 50 WATER-SHARING GROUP, WITH RELATIONSHIPS



A schematic of one Bhungroo system water-sharing group, No. 50. Copied from a drawing made in-field with one of the farmers. The numbers align between the map and the key, with a best attempt made to represent proximity of the fields to each other. Relationships were described by one of the Bhungroo system water-sharing members.

FIGURE 11. MAP OF PLOTS BELONGING TO BHUNGROO NO. 32 WATER-SHARING GROUP, WITH RELATIONSHIPS



This schematic shows the fields belonging to another Bhungroo water-sharing group: No. 32. Map was copied from an in-field drawing completed with farmers.

Schematics such as these help to show the spatial relationships between fields and the social complexity of the Bhungroo system water-sharing groups.

B. ADDITIONAL HARVEST TABLES

TABLE 14. ANNUAL CROP YIELDS FOR FARMS IN THE SWFF STUDY AREA, BY MAUND

	Castor	Millet	Wheat	Lentils	Mung	Cumin	Mustard	Cotton	Guar beans	Grass*
Number of interviewees growing	36	11	11	5	3	2	1	1	1	4
Total maund harvested	1,483	355	465	69.5	30	0	7	20	6	75
Average	41	32	42	14	10	0	7	20	6	18.75
Median	30	25	30	7.5	10	0	7	20	6	14.4
Number of crops lost	2	4	0	0	0	2	0	0	0	–
Percent loss	6%	36%	0%	0%	0%	100%	0%	0%	0%	–

Crop yields above are shown in maund. Same time period as Table 4, only different weight unit. Maund is the traditional weight unit of the region. Kilograms from table were converted from maund, 1 maund = 37.3242 kilograms, except for three grass values. For those, baskets and packets were given with estimated kilogram weights.

	Castor	Millet	Wheat	Lentils	Mung	Cumin	Mustard	Cotton	Guar beans	Grass*
Number of interviewees growing	36	11	11	5	3	2	1	1	1	4
Total pounds harvested	12,2030	29,211	38,263	5,719	2,469	0	576	1,646	494	6169
Average	3,390	2,656	3,478	1,144	823	0	576	1,646	494	1543
Median	2,469	2,057	2,469	617	823	0	576	1,646	494	1184
Number of crops lost	2	4	0	0	0	2	0	0	0	–
Percent loss	6%	36%	0%	0%	0%	100%	0%	0%	0%	–

Crop yields above are shown in maund. Same time period as Table 4, only different weight unit. Pounds are calculated from kilograms, 1 kilogram = 2.20462 pounds.

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