Exploratory study of Doha Model as a water harvesting structure

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Abstract

Maharashtra has a known history of farmer suicides fuelled by different reasons. A less than expected return from agriculture is one of the prominent reasons. This background lends importance to ensuring supplementary irrigation for crops and water harvesting is a credible means to achieve this end. This study explores the benefits and impacts of one less known water harvesting structure, Doha Model, in Yavatmal district of Vidarbha region of Maharashtra. Yavatmal has just 5% of the net sown area under irrigation, with 79% of total workers dependent on agriculture. This study collects both quantitative and qualitative data to explore the impacts of Doha Model on agriculture, livestock and domestic water use. It uses questionnaire survey and focus group discussion to collect data from 37 households. Study find out that the Doha Model has positively affected agriculture including cropping intensity and yield. It has also led to saving of opportunity cost of fetching water for livestock. However, there is no reduction in physical drudgery related to fetching water. Scope of benefits is limited to the downstream farmers closer to the stream and there is also a low sense of ownership of Doha Models in the local community. Study finds the immediate need for maintenance of these water harvesting structures.

1 Context of the study

Yavatmal district in the Vidarbha region of Maharashtra has a population of 2.7 million, 78% of which is rural as per the census 2011. It has a 30% population from ST and SC. Of the 1.4 million total workers identified in the district, 79% are dependent on agriculture – either as cultivators or as agricultural labourers. With just 5% of the net sown area under irrigation, agriculture is primarily rain-fed. Yavatmal falls under the Deccan plateau, semi-arid zone. The district has received an average annual rainfall of 891 mm over the last five years, but with a significant inter-year variability, ranging from 1317 mm to 618 mm. A lower than average rain-fall year means a lower final agricultural produce – in the absence of any irrigation sources. Moreover, Yavatmal has a known history of farmers suicides, which are fueled by a less than expected return from agriculture (Gutierrez, Ponti, Herren, Baumgärtner, & Kenmore, 2015).

Above background credits importance to water harvesting and its utilisation for supplementary irrigation in agriculture. There are several studies on the impacts of different water harvesting structures and their benefits. Study by (Kumar, Ramilan, Ramarao, Rao, & Whitbread, 2016) identifies that the farm ponds in Maharashtra have helped in increasing farm productivity and farm income. Another study across 70 villages of Maharashtra finds out that water harvesting measures have succeeded in raising the groundwater table based on local community's perception (Kerr, 2001). Government as well as non-government organisations (NGO) have been promoting different water harvesting measures with this objective.

1.1 Brief about the Doha Model

Doha Model is one such intervention, designed by an NGO named Dilasa Sanstha. Doha (pronounced as Ḍʳōha) refers to a saucer-shaped water storage structure. Conceptually, Doha Model is a percolation structure along the drainage line accelerating groundwater recharge. Doha Model are dug along the stream beds of the lower order streams through its natural course, leaving natural bunds in-between them.

Absence of any infrastructure construction makes Doha Model a low-cost micro water harvesting measure. Rainwater stored in these Doha Models is useful for irrigation, for household chores and it acts as a water source for livestock. It is considered to help in recharging the water table, thus increasing water level in the wells nearby. However, it is difficult to find any systematic study documenting its impacts in entirety – to help in deciding whether the benefits from this water harvesting technique are comparable to other small-scale water harvesting measures.

2 Objectives of the study

The primary objective of the study is to characterise the impacts of the Doha Model as a water harvesting structure.

This study is exploratory; It intends to explore impacts of Doha Model on agriculture productivity and income, changes in the drinking water availability to the human and the livestock population, groundwater table changes and other social and ecological impacts.

3 Methodology

3.1 Study areas

Study area for this study includes four villages from the Yavatmal district, selected through purposive sampling. These are Rajani, Dhangarwadi, Sarati and Ghoguldara. Of these Rajani and Ghoguldara are predominantly tribal villages, with population of 98% and 80%

respectively from scheduled tribes as per census 2011. Population in remaining two villages is a mix of different communities.

Doha Model in Ghoguldara were dug during the year 2009 and then in the year 2013. In the other three villages, this intervention was carried out in the years 2013 and 2014. Villages selected have a relatively long stretch of the stream under intervention ranging from 1 to 2 Km. These two criteria in selection of villages helped in identifying the maximum impacts of this intervention.

In the study area, depth of the stream bed from the ground, post-intervention, is up to 3 meters; streams have been dug up to a depth at which either gravel or stone started appearing in the soil strata. As part of the intervention, stream bed digging took place along the length of the stream in the stretches of 100 to 150 meters each – each such stretch called a Doha Model. Between every two such stretches, approximately a 10 meters long portion of the stream was left to its original state. At few places, along the stream, cement bunds are existing from before the intervention. Narrower portions of the stream were widened up to 6 or 7 meters.

3.2 Sampling

From the four villages selected for the study, 37 farmer households were selected through stratified random sampling to compare agricultural benefits. Sampling process involved dividing these households into treatment and control groups, with an assumption that farmers in immediate vicinity of the stream have an access to the stream water for irrigation, while those way from the stream do not possess such access. Treatment population comprises of 21 farmers having their agricultural fields in immediate vicinity of the streams – and the remaining 16 farmers constituting the control population have their agricultural fields far from the stream. As the study area witnesses direct pumping of stream water for irrigation rather than using wells, it is difficult to decide a threshold distance from the stream limiting agricultural benefits. However, for analysis, Study assumes a threshold distance of 200 meters from the stream separating the treatment and the control groups.

3.3 Data collection

Data collection for the study involved a combination of two methods – questionnaire survey and focus group discussion. Study uses a semi-structured questionnaire to collect data from the individual farmer households on agriculture. For treatment and control populations, survey was done to collect data for pre and post-intervention phases. Data collection is recall based, relying on the memory of the respondents, for both pre-intervention and the post-intervention phase – due to absence of any written records.

As the streams are accessible to every household in the village, any intervention on these can have a variety of impact on the entire population in the vicinity. Focus group discussions (FGD) with men and women from the village explored such benefits.

3.4 Analysis

This study employs the Difference-in-Differences (DID) method to analyse the impacts of the Doha Model intervention on agriculture. Analysis of the qualitative data collected through direct field observation and focus group discussions from the study area identifies other social impacts.

DID method compares change among the treatment group households to the changes among the control group households, for the post-intervention period. This method considers the changes due to intervention, as well as the changes which take place without the intervention during the same period.

4 Findings

Study findings look at the impacts of Doha Model on agriculture through changes in the water availability for irrigation, change in income from agriculture and changes in the cropping intensity. In an attempt to understand the impacts of the intervention on the groundwater table, study findings show the changes recorded in the water sources used for drinking and other household requirements. It also explores the impact of the intervention on livestock. Additionally, it presents the role of water harvesting structures on the uplands, as recorded through the discussions.

4.1 Agriculture

Agriculture practised in the villages studied is mostly kharif agriculture, either rain-fed or through supplementary irrigation. Irrigation source is primarily surface water in three of the four villages while in one villages, Sarati, people are dependent on groundwater through dug-wells. Households with irrigation sources take another short duration crop, post kharif, utilising residual moisture.

4.1.1 Additional water storage

Irrigation sources used by the respondents include, canal, dug wells and Phud – a gravity-flow based irrigation system. Participants, during discussions, reported the development of groundwater through dug wells to be a recent phenomenon – close to 70% dug wells owned by the respondents have been dug post-intervention.

Respondents reported the use of Doha Model for irrigation as water tanks post-intervention, in all villages; post-intervention water retention has increased by varying periods. Water is pumped directly from these streams by farmers into their agricultural fields for the extra days these streams retain water. For a Doha Model – 150 meters long, 7 meters wide and 3 meters deep – the storage capacity comes to 3150 cubic meters of water. With the rainfall in successive years, silt has set in the structures; therefore, assuming a 1-meter loss of depth to silt and errors of operation, the additional irrigation potential created in all four villages is in table 1. In Sarati, stream beds digging took place up to a depth of 1 to 2 meters from the ground, therefore the depth considered is 1 meter.

Table 1 additional irrigation potential created through Doha Model

Village	Stream length under intervention (in Km)	Change in the number of months stream retains water	Storage capacity created (in m^3)
Rajani	1.5	2	18900
Dhangarwadi	2	6	25200
Ghoguldhara	1.2	4	14700
Sarati	2	1	12600

The total number of farmer households in the village – including the sample population - availing irrigation from the Doha Model, as reported during the discussions is in table 2. Doha Models have provided a critical source of irrigation during kharif to the farmers practising rainfed agriculture.

Table 2 Number of farmers availing irrigation from Doha Model

Village	Rajani	Dhangarwadi	Sarati	Ghoguldara
Irrigation beneficiaries from the stream	12	60	55	11

4.1.2 Income from agriculture

Among the 37 respondents, those from the treatment group reported utilising this additional irrigation potential post-intervention - trend of their agricultural incomes reflect the same (table

3). Growth in the average agricultural income of a household from the pre-intervention phase to the post-intervention phase has been 38% for farmers in the treatment group, whereas it is only 5% for respondents from the control group.

Table 3 Average household income from agriculture

Category of farmers	Pre-intervention	Post-intervention	% change
Farmers having agricultural fields near stream	68942.38	95402.26	38%
Farmers having agricultural fields away from the stream	36731.25	38583.13	5%

4.1.3 Cropping intensity

Among the treatment group – farmers having their agricultural fields near stream – the percentage of farmers who were cultivating rabi crop has increased by 23%, from 6 to 11, post-intervention. While for the farmers away from the stream, it has stayed at zero both before as well as after the intervention.

Post-intervention, the average cropping intensity has increased for the farmers in the vicinity of the stream, while it has remained at 100% for the farmers away from the stream. Change in the cropping intensity shows only a nominal increase for the treatment group farmers – statistically not significant at 5% significance level (p-value = 0.067814). During the field visit, few farmers in the treatment group cited low rainfall during 2017 as the reason for not cultivating rabi crops. In Ghoguldara, respondents shared that there was a government order in 2017, asking farmers not to pump stream water for irrigation, which prevented them from cultivating rabi crops. Rainfall data for Yavatmal district also corroborates this finding; over the last two years, annual rainfall reduced from 977.3 mm to 618.8 mm, lowest in the last five years.

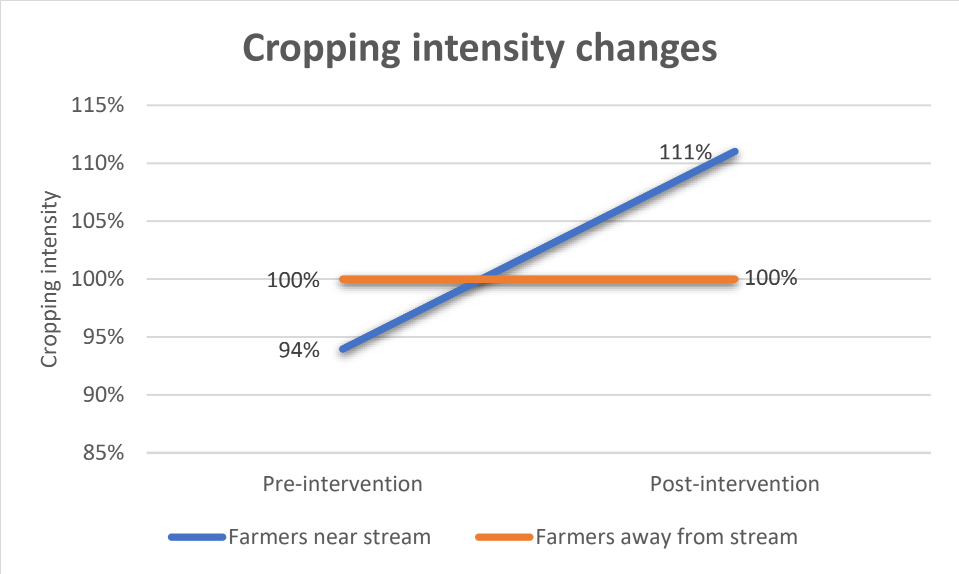

Figure 1 Cropping intensity changes post-intervention

Data analysis involves measuring crop diversity through Herfindahl crop-diversity index (HFI). HI values in figure 2 do not show a significant difference in crop diversity pre and post-intervention phases. Data explains this as close to 80% of the net cultivated land is under intercropping of cotton and pigeon pea for both types of farmers – both pre and post the intervention.

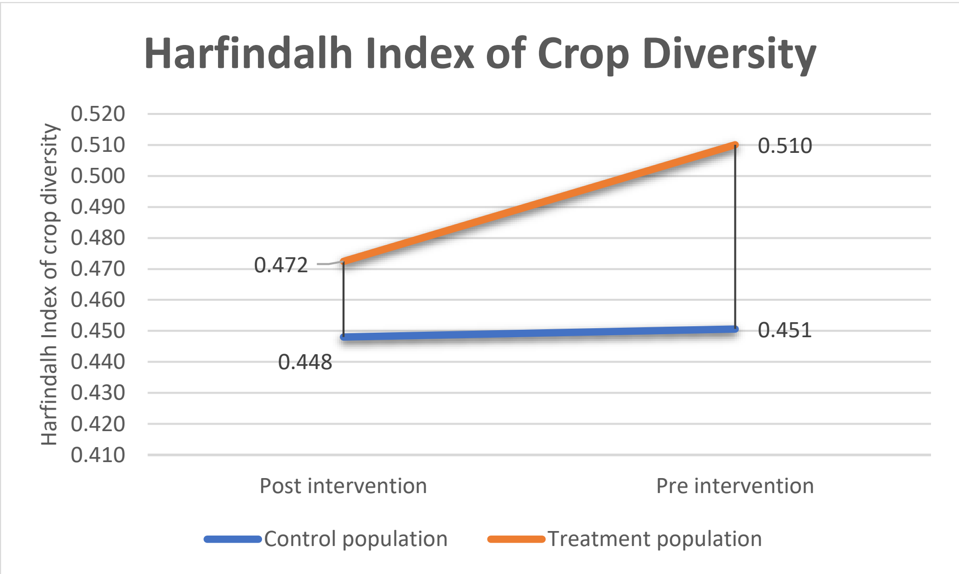

Figure 2 Cropping diversity changes post-intervention

Crop yield calculation for these two crops reveals that, Post-intervention yield of cotton has increased among all the respondents, but for the farmers having access to water from a Doha Model, it has increased by 21%, whereas for the farmers having their agricultural fields away from the stream, this increase been of 15% (figure 3). For pigeon pea, crop yield has increased by 6% for farmers having their agricultural fields near stream, and for fields away from the streams pigeon pea productivity has recorded a negligible change (figure 4).

Study applies a two-tailed t-test to check the statistical significance of the difference in crop yields across the two groups of farmers; it indicates that the yield difference for both the crops across the two groups is significant at 5% significance level – p-value for cotton is 0.000896 and p-value for pigeon pea is 0.002812. However, a t-test comparing crop yields changes pre and post the intervention within the treatment group shows that this change is not significant for both cotton and pigeon pea at 5% significance level - p-value for cotton is 0.041287 and p-value for pigeon pea is 0.43495.

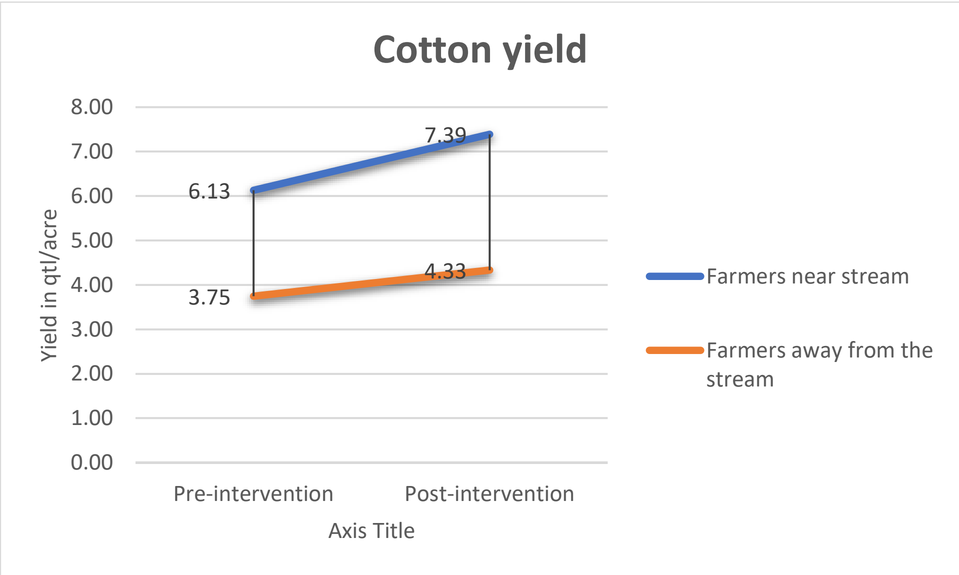

Figure 3 Cotton yield (in quintal/acre)

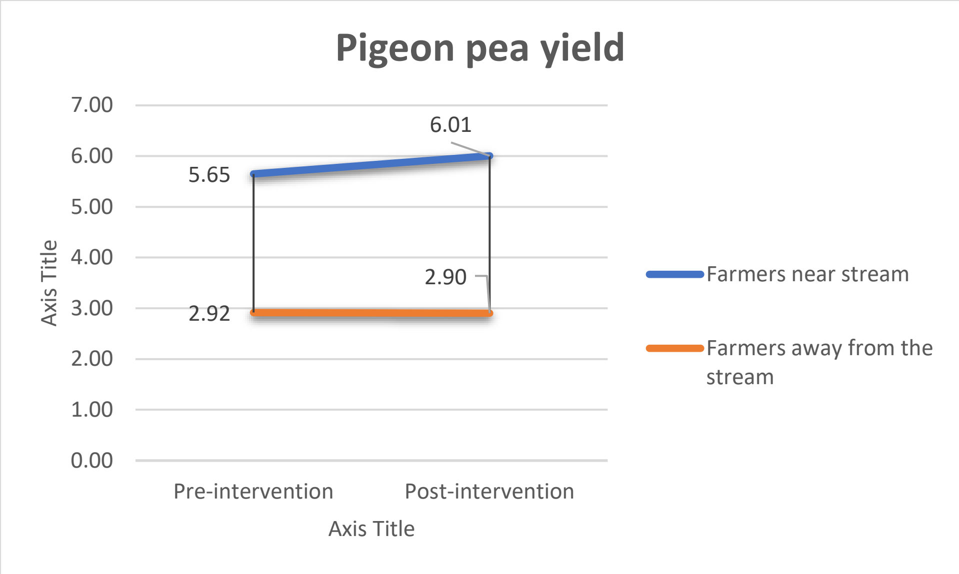

Figure 4 Pigeon Pea yield (in quintal/acre)

4.2 Water use for drinking and other household requirements

Dug well is the most critical source of water in the study area; in three villages, people are using dug wells to fulfil all households water requirements. In two villages, these are gram panchayat owned dug wells, while in one village, it is a privately owned dug well. These wells are near streams, which were part of the intervention. Information about sources of water, both pre and post intervention is in the table 5.

Table 4 Sources of water for various household uses

Village	Drinking pre-interventio n	Drinking post-interventio n	Bathing pre-interventio n	Bathing post-interventio n	Other domestic usage pre-intervention	Other domestic usage post-intervention
Rajani	Dug well	Dug well	Dug well	Dug well	Dug well	Dug well
Dhangarwa di	Borewell	Borewell	Dug well /Borewell	Dug well /Borewell	Dug well /Borewell	Dug well /Borewell
Sarati	Dug well	Dug well	Dug well	Dug well	Dug well	Dug well
Ghoguldhar a	Dug well	Dug well	Dug well	Dug well	Dug well	Dug well

Discussions with villagers revealed that in two villages, water level of drinking water wells has increased; in one village, well retains water for three more months post-intervention. However, in both these villages, Doha Model digging has been followed by deepening of the wells, hence the impact cannot be attributed to the intervention alone. Figure 3 shows the water level in drinking water wells of three villages; depth of these wells from ground are different from one another.

Once the designated drinking water wells dry off, people fetch water from other privately owned dug wells. At no point in time, water tankers were used to supply water in the studied villages. Post-intervention, a supply pipeline has been installed in one village easing the physical drudgery related to fetching water. However, women from other village do not perceive any significant impact of this intervention on their physical drudgery. Vimal Sitaram Kove from Rajani said that “*we still have to make 8 to 10 trips to the drinking water well every day; It causes pain.”* Men from the village, help women during the lean season by fetching water in drums, on bullock carts, from privately owned dug wells; it has continued post-intervention. A fraction of households in another village, Dhangarwadi – in an attempt to reduce the drudgery associated with fetching water – has shifted from using handpumps to using a privately owned borewell, paying Rs 300 monthly since over a year.

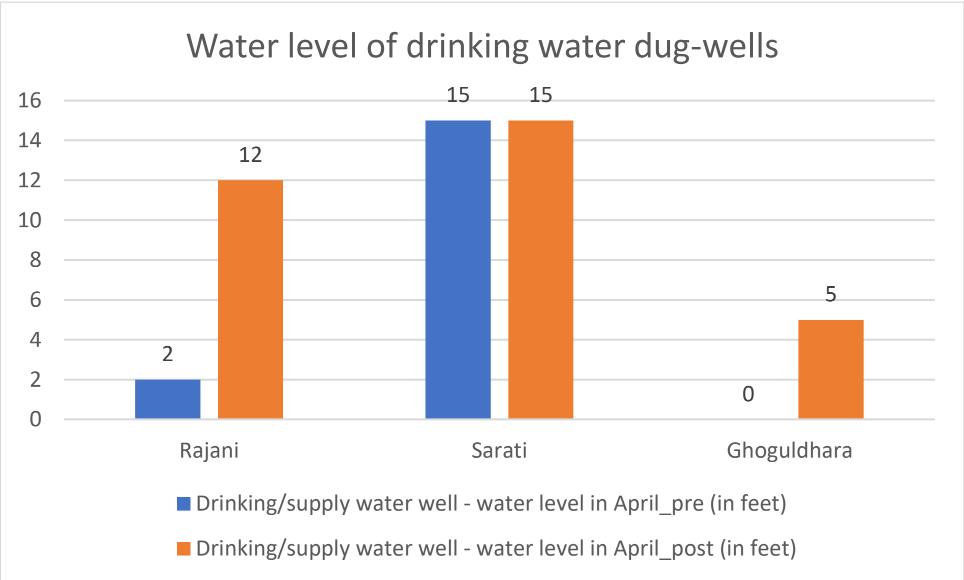

Figure 5 Water level of drinking water dug-wells (in feet)

4.3 Livestock

Respondents from one village under study practice livestock rearing as a livelihood, in the form of sheep and goat rearing. In other villages, people own cattle to support their agriculture and household milk requirements.

Streams were reported to be the primary source for the livestock water requirements. Therefore, the additional number of days stream retains water post monsoon directly translates into the additional water availability for livestock. Figure 4 shows the village wise information on the change in the number of months streams retain water post-intervention, as reported by villagers.

In Rajani, the stream retains water for two more months post-intervention. The opportunity cost of two month's labour in arranging water for cattle come to Rs 3000 per household. Assumption made in the calculation include, wage rate taken as Rs 200/day which is the prevailing wage rate for men in the village and a two-hour labour required in arranging water from the alternate sources which are at least 1 km far from the village habitation area.

In other villages, alternate water sources are available within the village habitation area; also, there is a practice of hiring a herdsman for a group of households in two villages, who herd cattle to the water sources. Hence a significant saving of time and labour was not reported in other villages.

In none of the villages, respondents reported starting cattle feed cultivation post-intervention. Also, it was reported during the discussions, that there has not been any change in the number of livestock animals owned by the households post this intervention.

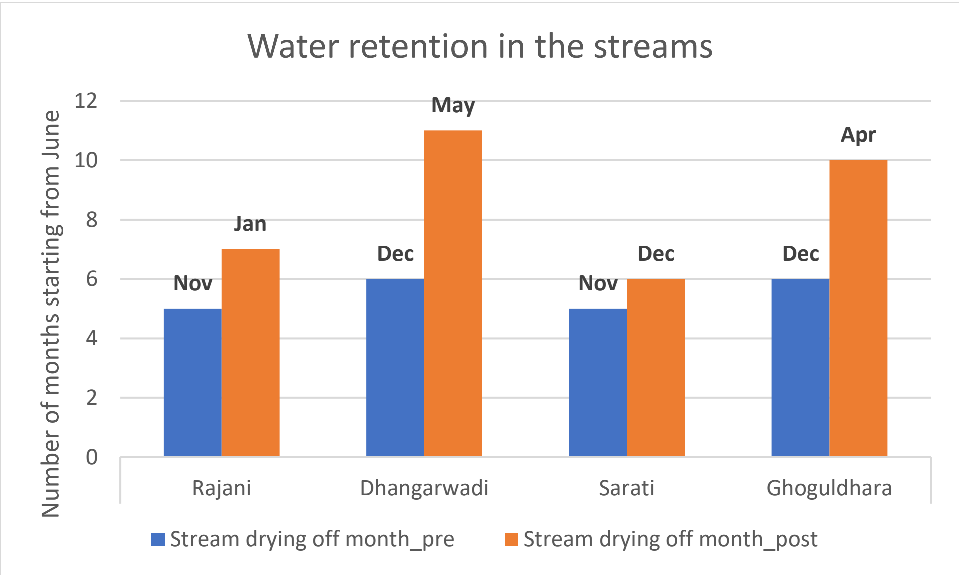

Figure 6 Water retention in the streams

4.4 Water harvesting upland

In two villages Dhangarwadi and Ghoguldhara, streams have small dams upstream storing monsoon run-off from the upland. In these villages, participants reported stream water retention for longer duration, post-intervention, as compared to the other two villages where there is no such structure. It indicates that a water storage structure upstream, such as a pond helps the stream in retaining water for a longer duration

5 Limitations

5.1 Benefits to a limited population

This intervention has put the farmers, having agricultural fields near stream, at an advantage over those having their fields further from the stream – through provision of access to irrigation through the stream. Although, farmers have an equal access to the stream, but its utilisation is dependent upon the financial capacity of the farmer. Krishna Rama Ahir from Dhangarwadi shared during the discussion that "*for irrigation, people carry water up to 1000-1500 feet using diesel engines and pipes. Only those who can spend money on transporting can avail this type of irrigation.*"

Similarly, in the studied villages, as one traverses from upland to low land, soil changes from dark brown to black cotton soil. Low lands are thus better suited for growing cotton, a crop cultivated by 100% respondents in the study. Streams – mostly eluding the uplands – are flowing through the drainage area having the black cotton soil. Even in the streams, which flow through a part of upland, participants reported during the discussions that downstream water retention is better than upstream. It has given lowland farmers an additional benefit in terms access to irrigation, leading to an increase in the already existing economic disparity within the community.

5.2 Community participation

The implementing NGO estimates the life-span of a Doha Model to be four to five years. At the time of the study, all the streams, where intervention has taken place needed desilting and rejuvenation. Respondents also shared an immediate need to desilt these structures, in all four villages. However, in none of the villages, they shared a willingness to do it on their own. At the same time, in one village community has engaged in some voluntary watershed work as part of a recent initiative by another civil society organisation. Local community groups to look after maintenance of these structures do not exist. Women in the villages under study feel excluded from the process of intervention. They perceive the intervention to be beneficial only for agriculture.

6 Conclusion

This study shows that Doha Model is a potential small-scale water harvesting structure which can address critical irrigation requirements through surface water. Study findings indicate that the Doha Model intervention has a significant impact on agriculture. After the intervention, cropping intensity has increased for farmers near the stream; crop yield has also increased for cotton and pigeon pea which occupy 80% of the net cultivated land, though the change is not statistically significant. Cropping diversity does not show a significant change post-intervention, indicating farmers' preference for intercropping of cotton and pigeon pea. Water level in the drinking water dug-wells has increased, but there is no consequent reduction in the physical drudgery related to fetching water. Stream water availability for livestock has increased after this intervention leading to saving of opportunity cost, in situations where the alternate water source is far from the village.

Doha Model intervention has few limitations and challenges, like any other water harvesting measure. Agricultural benefits of Doha Model are limited to the farmers whose agricultural fields are in the vicinity of the stream and to the downstream farmers. There is a low sense of ownership of this intervention among the local community especially women. Also, there is no village level committee or group to look after the maintenance of the intervention.

One crucial inference coming out from the study is the need for regular maintenance of the Doha Model. A committee or group of water users can help in ensuring in maintenance as well as regulation of the stream water use for maximum benefits.

7 References

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