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Surface rainwater harvesting potentiality and impact of Dhaval micro-watershed in Satara district, Maharashtra, India

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Abstract

The main objective in constructing the rainwater harvesting structures is to collect and retain the maximum possible amount of runoff generated from its catchment area. If suitable small surface water harvesting structures are taken up systematically on a micro-watershed basis, it is possible to avoid the drought like conditions that prevail in semi-arid regions. The present paper based on the primary data collected by conducting intensive fieldwork and personal interviews. It is found that three main surface water harvesting structures have been constructed. These are - i) Cascade of tanks and contour bunds ii) Networking of farm ponds iii) percolation tank. It is suggested that such surface rainwater harvesting structures should be constructed in a micro-watershed particularly in the drought-prone areas to bring prosperity and development.

Key Words: Water harvesting, Potentiality, Micro-watershed, Impact, Sustainable development.

1. Introduction

India has an age-old tradition of water harvesting. We find early evidences of this tradition right from the time of the Harappan civilization. Harappan people were well versed in the construction of storage tanks, well irrigation, built temporary bunds across streams.

The term water harvesting refers to collection and storage of natural precipitation. It's aimed at harvesting rooftop, surface and ground water. Prevention of losses through evaporation and seepage and all other hydrological studies and engineering interventions aimed at conservation and efficient utilization of the limited water endowment of physiographic unit, such as a micro-watershed. The watershed is also referred to as the catchment area of a stream.

The basic objective in constructing a surface water harvesting structure is to collect and retain the maximum possible amount of runoff generated from its catchment area. The dictum "small is beautiful" seems to be holding good for surface water harvesting also. The reason is not only economical but also scientific.

The selected Dhaval percolation tank micro-watershed falls in drought prone region of western Maharashtra. Surface Water Harvesting (SWH) has been practiced very widely in this region, where some of the tanks constructed in a drought year 1972 are still in use. We find that the SWH structures are more prevalent in areas covered with igneous rocks (hard rock). In the northern side of Dhaval percolation tank, It was found the tradition of constructing a series or cascade of tanks, wherein the overflow from the upstream tank was led to the storage area of the next tank down the course of stream (Athavale, 2000). All this suggests that the smaller the catchment area, more efficient is the runoff collection. The farm pond becomes the most appropriate water harvesting structure. Next to farm ponds, are the water harvesting structures of intermediate size variously referred to as small tanks, contour bonds and mini percolation tanks.

2. Objectives

2.1 To measure the potential of cascade system of small tanks and contour bunds constructed in the upper reaches of micro- watershed.

2.2 To monitor the capacity of farm ponds constructed in the cultivated area.

2.3 To determine the impact of percolation tank constructed near the out-flow point of the micro-watershed.

3. Data Source and methodology

The entire information and data required has been collected by organizing frequent field trips in the study area. The data is generated with the help of household schedule by conducting personal interviews and observations were also made for comprehension of geographical conditions. The information and data for the selected watershed have been obtained from the Minor Irrigation Department, Government of Maharashtra. A cadastral map obtained from the Dept. of Land Resource, Satara district has been used to determine the area benefited from the percolation tank in the command area. To assess the socio-economic impact 10 per cent of 300 farmers from the command area have been selected by adopting stratified random sampling technique. Besides this, statistics regarding land use, cropping pattern, size of holdings, etc. for respective years have been procured from the village officials such as village account officer (Talati) and administrative Officer of Village (Gram Sevak). For preparation of isoline maps depicting water table before the construction of tank in 1980-81 and after the construction of tank in year 2004-05. After the construction of percolation tank several field trips were organized in different seasons. Then annual average water tables were calculated by making the average for different periods.

4. The Study Region

The Dhaval percolation tank a micro-watershed undertaken for the present study is located in southern part of Phaltan tahsil in Satara district (Maharashtra). It lies between 17° 50' north to 18° 5' north latitudes and 74° 10' east to 74° 20'east longitudes (Fig.1).

In this region, it is a normal phenomenon that the monsoons fail once in 5-10 years. However, the increased water availability through micro-level water harvesting measures the provision of one or two supplemental irrigation to the existing crop at critical stages can be made possible with which the yields can be improved dramatically. This is possible by adopting surface water harvesting methods on a micro-watershed. The command area of percolation tank is about 372.72 hectares and its catchment area is 400 hectares.

5. Feasibility and need of rainwater harvesting in the region

5.1Climatic condition

This area falls in the rain shadow zone of Western Ghats receiving rainfall on an average of 549 mm. The annual average rainfall has observed more than the normal for ten years the year 1998, has recorded highest rainfall, (864.3 mm). Contrasting to this, there are some years, which are marked by rainfall less than normal. Nearly 10 years have recorded this situation and the year 2003 marked lowest rainfall (235.2 mm). Remaining years have recorded normal rainfall. All these temporal variations have close link with the availability of water. The said analysis reveals that there is dire need of rainwater harvesting in the region.(Fig.2)

5.2 Geological formation

The region belongs to Deccan traps basaltic lava flows of Upper Cretaceous to Lower Eocene age and located at the western limits of it. The denudation slope on Deccan traps attains their maximum thickness near Tathavda hills which are the sub ranges of Western Ghats. These flows occur in layered sequence ranging in thickness from 4 to 66 m. Flows are represented by massive portion at bottom and vesicular portion at top and are separated from each other by marker bed known as bole bed. In Basaltic area, the artificial recharge structures feasible are check dams, gully plugs, percolation tanks, nalla bunds, etc.

5.3 Water Level Trend (1998–2007)

Long term water level trend for pre-monsoon and post monsoon periods for last 10 years (1998–2007) have been computed and analysed by Groundwater Survey Development Agency (GSDA) department, Satara district. The analysis indicates that during pre-monsoon period rise in water levels ranging between negligible at few National Hydrograph Network Stations (NHNS) and 0.56 m/year (Tathvade village) have been recorded at 26 NHNS. During post-monsoon period rise in water levels have been recorded at 28 NHNS and it ranges from negligible at few NHNS to 0.32 m/year (Dhaval village) have been recorded. Thus the future ground water conservation and recharge structures need to be prioritized in these areas. (Prabhat Kumar Jain,2009)

6. The potential

Conceptually the total amount of water that is received in the form of rainfall over an area is called the rainwater endowment of that area. Out of this, the amount that can be effectively harvested is called the water harvesting potential. In the selected watershed through the development of following surface water harvesting system, the natural sites should be utilized to store the rainfall runoff water.

6.1 The cascade system of small tanks constructed at the upper reaches of a watershed

This is the most prevalent form of traditional water harvesting system. That makes possible to store the maximum rainwater in different seasons, useful agriculture purposes. The first and second order streams at Dhaval percolation tank micro-watershed constructed of cascade system of small tanks in the drought year of 2002-03. Out of 150 ha about 40 per cent catchment area was uncultivated, 50 per cent was cultivated and remaining 10 per cent was cultivable waste land. About 5 villages namely Tathawada, Dhaval, Dalawadi, Veloshi and Upalve fall in this catchment area. In the catchment about 10 small tanks have been constructed in 2003 (Fig.3). The said sites are enabled to collect the drained out excessive water from the upper located tank to the lower one and so on. One of the disadvantages of the grouping of tanks is, if a breach occurs in an upper tank, it exposes all the tanks in the series below to the risk of similar failures. Repairs or restoration work in such cases can be done collectively rather than individually.

The catchment area of all cascade small tanks is 100 ha rainwater harvesting potential calculated is 20 Thousand Cubic Meter of which each dam of 2 TCM capacity. After having, constructed of such small tanks in the watershed, the impact of these are observed, for instance, rise in ground water level (1-2 metre), increase in duration of water availability in the wells, change in cropping pattern, reduction in soil erosion and development of the social forestry.

6.2 Contour bunds constructed in the upper reaches of a watershed

***6.2.1* Contour bunds for trees**

Contour bunds for trees are a simplified form of micro catchments. Construction can be mechanized and the technique is therefore, suitable for implementation on a larger scale. The sites of the constructed contour bunds are near the Upalve and western hill slope of Veloshi village. These sites are having more than 4 per cent of slope and 75 hectares catchment area covered. Advantage of contour bunds is their suitability to the cultivation of fodder. As in the case of micro-catchment water harvesting techniques, the yield of runoff is high, and when designed correctly, there is no loss of runoff out of the system (Fig. 4 and Table 1).

***6.2.2* Semi-circular bunds**

Semi-circular bunds are earth embankments in the shape of a semi-circle with the tips of the bunds on the contour. Semi-circular bunds, of varying dimensions, are used mainly for rangeland rehabilitation or fodder production. This technique is also useful for growing trees and shrubs. In the upper reaches of micro-watershed area of reserve forest near the Tathavada village semi-circular bunds have been constructed. Slope of the region is more than 3 per cent., and 90 ha area is covered by reserve forest. After the construction of semi-circular bunds peoples have done tree plantation under social forestry scheme of Government forest department (Fig.4 and Table 1)

6.3 Farm ponds constructed in the cultivated area

In the cultivated area it is not always feasible to construct series of small tanks to harvest water due to less number of 1st & 2nd order streams and having slope less than 3%. However, this part is suitable for farm ponds. A series of ponds located in the upper reaches of the watershed help to retain good soil moisture regimes throughout the watershed. It is constructed along contour lines and to be connected to one another; (Fig. 4), will allow easy access to water and a better soil moisture regime.

About 50 ponds are constructed in the villages namely Dhaval, Upalve,Wakhari, Dalavadi and Kuravali. With each pond having a capacity of 1.2 Thousand Cubic Meter (TCM), in one filling as much as 50 million liters can be harvested (Reddy, 1988). Most of this water percolates down, and in a normal rainfall year these ponds can be expected to overflow at least three times. With the first peak of monsoon in June-July, all the ponds overflow. With subsequent rains, the ponds get filled up. With second peak of rains in August-September, when maximum rains are received, the ponds overflow more than once. The harvested water is used to irrigate horticultural crops like mango, grapes and any other similar types of plants for their initial establishment.

Fortunately, Govt. of Maharashtra has approved the ponds as effective rainwater harvesting systems and earmarked funds for their regeneration. The government has launched a scheme with the stated objective of ‘every village should have a village pond’.

6.4 Percolation tank constructed in the out-flow point in the watershed

Percolation tanks are the most prevalent form of traditional water harvesting system where the water stored in percolation tanks has been used directly and indirectly for domestic and irrigation purpose. There should be a mechanism to overcome the difficulty of erratic nature of monsoon rainfall, so that the some water accumulated through this system is useful for agriculture in arid and semiarid region.

Out-flow point in the watershed is located at southern site of Dhaval village. In the year 1986 Dhaval percolation tank built at this site.(Fig.5) The geomorphologic conditions in Dhval villages are favourable for construction of

percolation tanks. In this zone most of the people depend on only ground water source for all purposes. However, the ground water level is depleting fastly (GSDA, 1973). After the construction of percolation tank about 6 million cubic metre of water will be made available. It will help to fulfil the need of water of surrounding five villages for drinking, domestic and irrigation purpose.

7. Impact analysis

7.1 Augmentation in ground water

Before the construction of percolation tank, there were twelve dug wells in 1981. The depth of these dug wells varied from 7 metres to 16 metres below the ground level and diameter varied from 5 to 7 metres.(Fig.6.). The water level in these wells in winter season was 2 to 2.5 metres; however, most of these wells go dry in summer. As a result, these wells were providing water for 16 ha of land during the Kharif season only.

During the post construction period, twenty-four new dug wells and thirty tube wells were drilled with an average depth of 30 metres. Each tube well is providing water of about 2.5 ha of cropped area. In case of dug wells, the water level has increased by 1.5 to 4.5 metres and duration of the water in these wells has extended by two months i.e., up to the month of March. The yield of the dug wells has also increased significantly. As much as 84.65 ha of land has been brought under irrigation by wells and tube wells. All these facts reveal that there is significant augmentation in ground water in the command area during the post construction period. It is noted that the construction of a well should be at least at a distance of 100 metres from another well; otherwise this system will not be economical.

7.2 Changes in cropping pattern

In 2005 out of the total cropped area, 88.19 per cent was occupied by food crops, of which food grains shared 60.18 per cent and 24.92 per cent by sugarcane. Among the non-food grains, beans (Ghevda) accounted for 08.35 per cent. Among the cereals, Jowar (35.19%), and wheat (7.89%) are important crops. During 1980-81, about 85.96 per cent of the gross cropped area was occupied by food crops of which 77.94 per cent was shared by food grains and 28.26 per cent by sugarcane.

Among non-food crops, groundnut (10.58%) was dominant (Table.3). In the command area sugarcane is the major cash crop, the land of which has increased by 20.65 per cent, during the last two decades. Per hectare yield of sugarcane has also augmented form 40 tons to 60 tons.

Increased irrigation facilities, assured water supply by tube wells, nearness to sugar factory and sugarcane crop, being a symbol of status are some of the reasons for the increase in area under this crop. Sunflower is an oil seed crop and pomegranate and grapes are important fruit crops, which have recently been introduced by the farmers.

During the period under review, there has been a remarkable change in the respective positions of crops. Among the major crops, the highest decline is observed in Bajra (9.65%) followed by pulses (7.6%).Various crops, which recorded increase are sugarcane (20.65%) and Sunflower (1.13%). It is interesting to note that a crop of Mulberry plant leaves used for silk industry, is perennial water-demanding crop cultivated on 97.10 ha of land.

7.3 Socio-economic changes

Among the 300 beneficiaries, 30 farmers were selected by stratified random sampling methods. The results of the analysis are as follows

7.3.1 Size of holdings

In an agro-based society, land holdings have immense importance. It is one of the major parameters to evaluate the socio-economic status of the farmers (Pawar, 2003). At present about 57.65 per cent farmers are marginal landholders followed by small (26.22%) and moderate holders. As compared to the base year there is a slight change observed in the proportion of large size

7.3.2 Area irrigated

The cropping pattern; intensity of cropping and crop productivity depend upon the availability of assured irrigation facilities. The farmers with assured irrigation facilities adopt modern agricultural technology earlier than other farmers (Pawar, 1989). About 67.90 per cent of the farmers have irrigated land below 0.5 hectares while 20.52 per cent have between 0.6 and 1.0 hectares and about 11.58% have above one hectare of irrigated land. As compared to the base year, increase in irrigated is found in the moderate size of holdings. This is mainly due to increase in the irrigated area from 265.8 ha to 372.72 ha because of increased in ground water reservoirs in the percolation tank command area.

7.3.3 Education

Education is one of the prime indicators of development of human beings. Higher education leads to a positive approach towards adoption of agricultural innovations. During the base year about 33% farmers were illiterate, about 25% had completed their primary education and another 7% had entered secondary schools.

However, during the last 2 decades considerable change in educational attainment has been observed. None of them is illiterate, and over 25% having education of secondary and higher education level.

8. Conclusion

- This area falls in the rain shadow zone of Sahyadri mountain receiving rainfall on an average of 549 mm., it is a normal phenomenon that the monsoons fail once in 5 to 10 years. The said analysis reveals that there is dire need of rainwater harvesting in the region. The geology of the area feasible for the artificial recharge structures are check dams, gully plugs, percolation tanks, nalla bunds, etc.
- Due to surface rainwater harvesting programme in Dhaval percolation tank micro-watershed basis, recharge of ground water has increased, resulting in the rise in the water table leading to increase in yield and duration of well water and assured irrigation facilities.
- In the catchment area after the construction of the cascade system of small tanks and semi-circular bunds peoples have done tree plantation under social forestry scheme Government of Maharashtra state forest department.
- In the command area the significant change in cropping pattern has taken place. Farmers have switched over from cereals to cash crops. The increase in per hectare yield has also been noticed.
- The consequential impact of all these factors have been on increasing the socio-economic status of farmers. It is found that such schemes of micro water harvesting development at micro-watershed level would be a panacea for rural development. It is suggested that such a type of projects of micro-watershed should be undertaken in semi-arid or drought-prone areas at large scale to mitigate the drought conditions with which poverty in lagging regions can be reduced and will help in bringing the sustainable development in a conducive man-made green environment.

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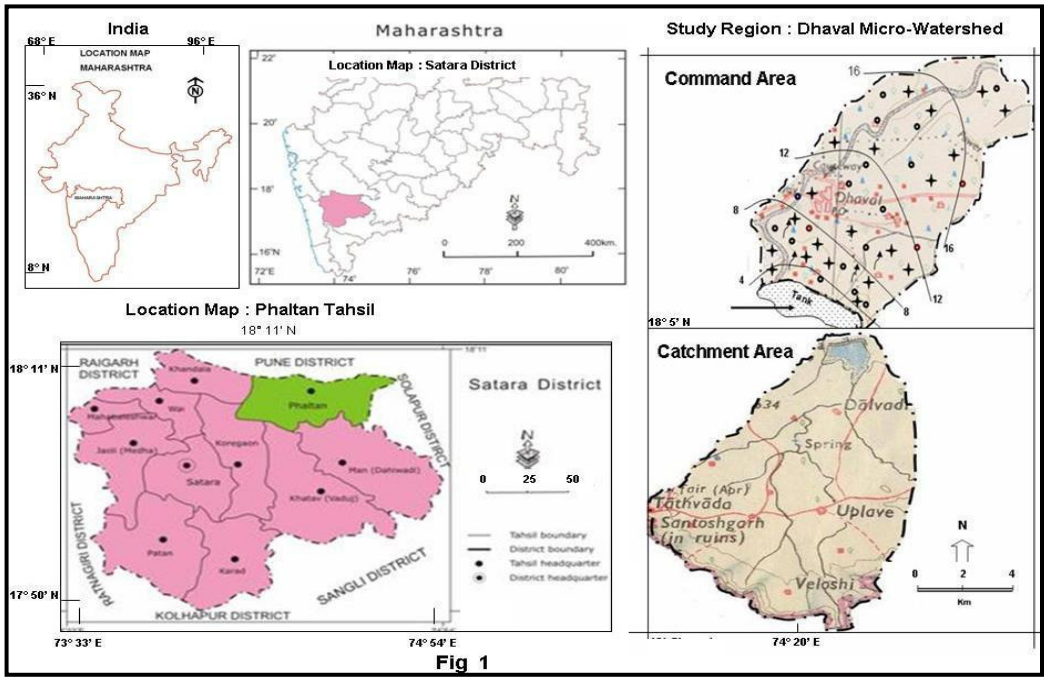


Figure 1. Study area location map

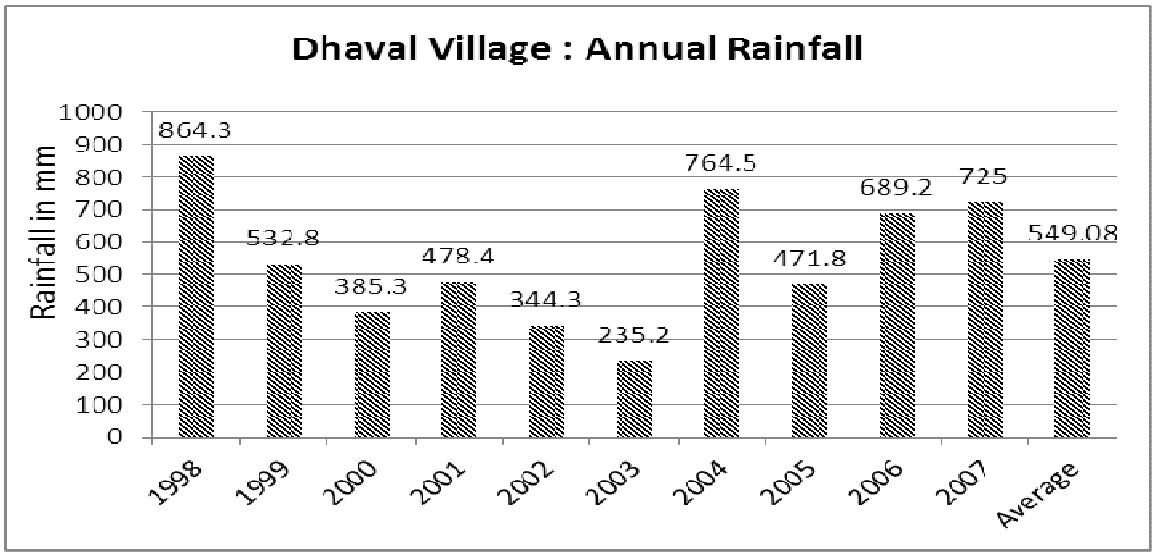


Figure 2 : Annual average rainfall 1998 to 2007

Figure 3. Cascade system of small tanks

Figure 4. Contour bunds around percolation tank

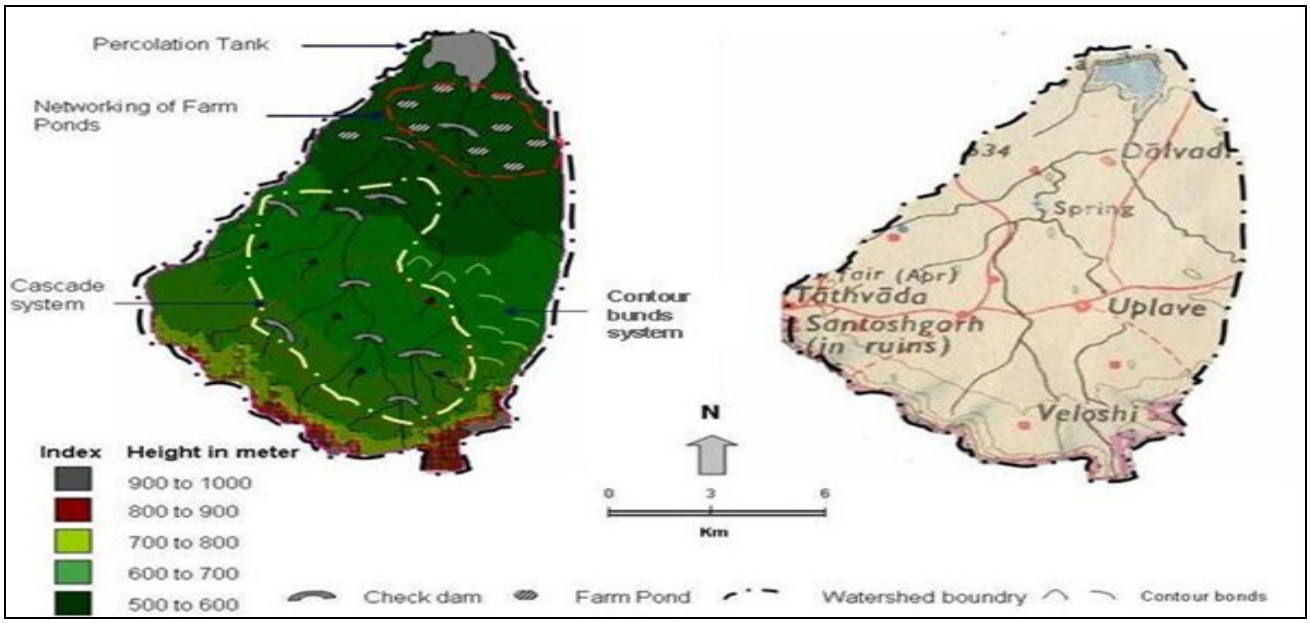


Figure 5. Surface rainwater harvesting structures constructed at Dhaval percolation tank micro-watershedcatchment area.

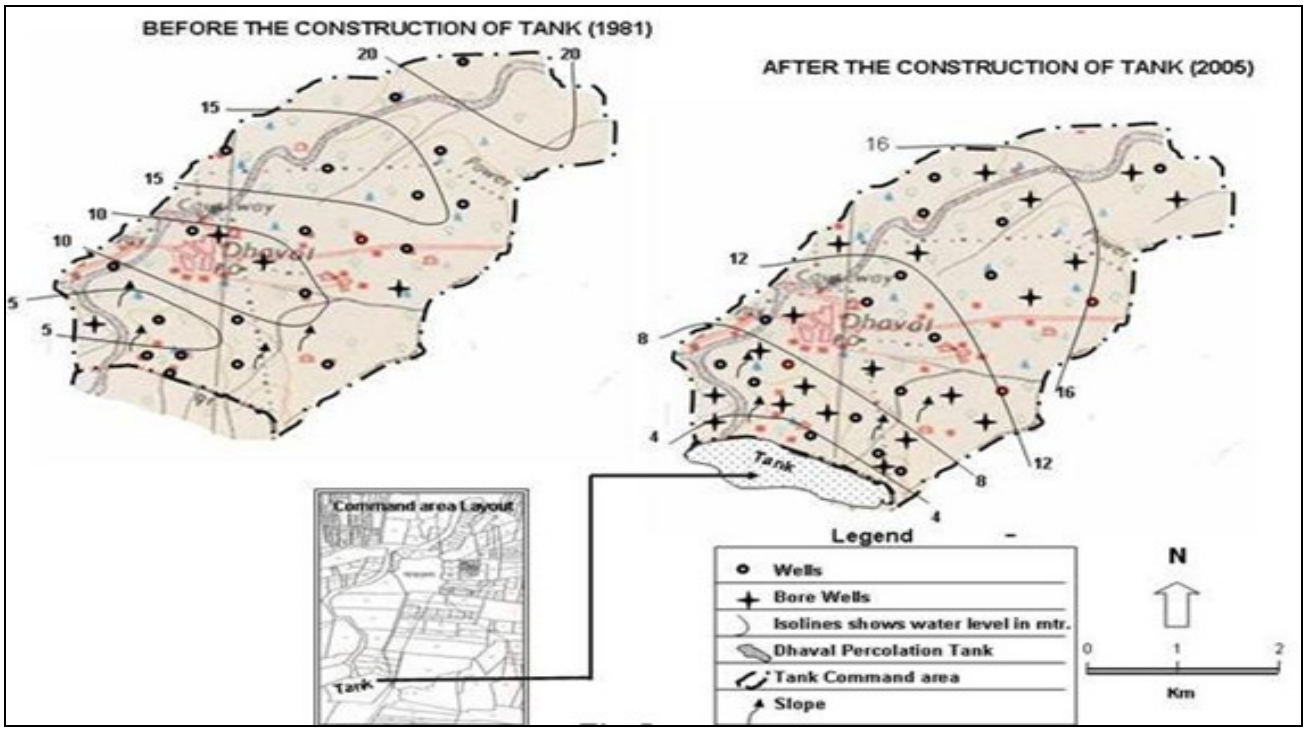
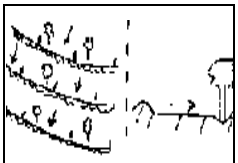
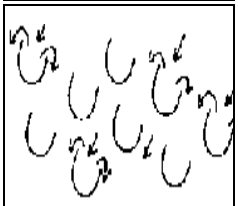


Figure 6. Dhaval percolation tank command area: Isolines showing water table

Table 1. Surface rainwater harvesting through contour bunds

Types & Slope in %	Classification	Catchment in hectars	Main Uses	Description	Appropriate locations	Layout
Contour Bunds	Micro catchment (short slope catchment) technique	75	Trees & grass	Earth bunds on contour spaced at 5-10 metres apart with furrow upslope and cross-ties	For tree planting on a large scale especially when mechanized **(In the upper reaches of a watershed – Near the Upalve & Dalawadi Villages)**	
Semi Circular Bunds	Micro catchment (short slope catchment) technique	90	Rangeland & fodder(also trees)	Semi-circular shaped earth bunds with tips on contour. In a series with bunds in staggered formation	Useful for grass reseeding, fodder or tree planting in degraded rangeland **(Surrounding Area of Tathavada Village Reserve Forest land)**	

Source : Crichley (1991) and based on field work.

Table 2. Surface water harvesting potential in study region

SWH Structure Name	**Number of structures**	**Location**	**Catchment area**	**Command area**	**Potential in cubic metre in year**
Small Tanks (Cascade System)	10	Upper reaches of a watershed near Veloshi, Upalve and Tathvada village	150 (15 ha Per small tank)	100 ha	20 Million Cubic Metres
Contour Bunds	-	Near the Veloshi, Upalve and Surrounding Area of Tathavada Village Reserve Forest area	165 ha	-	-
Networking of Farm ponds	50	Cultivated area near the Upalve and Dhaval village	250 (5 ha Per farm pond)	160 ha	60 Thousand Cubic Metres (TCM)
Percolation Tank	01	Southern site of Dhaval village	400 ha	372.72 ha	06 Million Cubic Metres

Source: Based on fieldwork, 2005-06.

Table 3. Dhaval percolation tank command Area: changes in cropping pattern

Sr.No.	Crops Change	1980-81		2004-05		Volume of change in per cent
		Area in hectares	Percentage in total	Area in hectares	Percentage in total	
1	Jawar	133.43	35.80	131.16	35.19	-0.61
2	Bajara	66.04	17.72	30.09	8.07	-9.65
3	Wheat	31.54	8.46	29.4	7.89	-0.57
4	Rice	-	-	-	-	-
5	Total cereals	231.01	61.98	190.65	51.15	-10.83
6	Gram	-	-	2.54	0.68	0.68
7	Other pulses	59.44	15.95	31.13	8.35	-7.6
8	Total pulses	59.44	15.95	33.67	9.03	-6.92
9	Total food grain	290.45	77.94	224.32	60.18	-17.76
10	Sugercane	15.91	4.27	92.87	24.92	20.65
11	Vegetable fruits	13.97	3.75	11.53	03.09	-0.66
12	**Total food crops**	**320.33**	**85.96**	**328.72**	**88.19**	**2.23**
13	Ground nut	39.46	10.58	30.02	8.05	-2.53
14	Sunflower	-	-	4.23	1.13	1.13

15	Total oil seeds	39.46	10.58	34.25	9.19	-1.09
16	Tobacco	-	-	-	-	-
17	Other non-food crops	12.92	3.46	9.75	2.62	-0.84
18	**Total non-food crops**	**52.39**	**14.04**	**44.00**	**11.81**	**-2.23**
Gross cropped area	-	372.72	100	372.72	100	+ 2.23 -

Source: Socio-economic review& district statistical abstract of Satara district, 1981 & 2005, and village records.

Table 4. Area under cash crops (hectors)

Size of holding year	Nil	< 0.5	0.6 to 1.0	> 1	Total
1980 – 81	53.37 (15)	31.14 (11)	8.92 (2)	6.57 (2)	100 % (30)
2004 - 05	30.00 (9)	45.13 (14)	13.15 (4)	11.72 (3)	100 % (30)

In the bracket shows number of farmers

Table 5. Agricultural implements

Types year	Traditional	Traditional & Modern	Total
1980 – 81	100.00 (30)	--	100% (30)
2004 - 05	72.55 (25)	27.45 (05)	100 % (30)

In the bracket shows number of farmers

Table 6. Annual income (in Rs.)

Income Year	< 25,000 Low Income Group	25 to 50,000 Moderate Income	> 50,000 High Income Group	Total
1980 – 81	83.23 (21)	10.32 (7)	6.45 (2)	100 % (30)
2004 - 05	54.00 (9)	25.45 (15)	20.55 (6)	100 % (30)

Source : Based on fieldwork (in the bracket number of farmers)