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Mitigation of climate change impacts by intensive rainwater harvesting, unproductive waste lands development and intensive plantations in a vulnerable semi-arid ecosystem of Rajasthan

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ABSTRACT

Aravalis are considered as one of the most degraded ecosystems of India. Harsh climate, low and erratic rainfall, thirsty and hungry sandy soils, fuel, fodder and water scarcity characterize the bio-physical setting of this arid region forming northern edge of the Thar Desert. Irrigated agriculture expanded disregarding low rainfall and limited scope of groundwater recharge. The introduction of wheat and vegetable crops against *Pennisetum glaucum* (Pearl Millet) and *Brasica nigra* (Mustard) the native crops of the region led to drastic fall in water table necessitating the installation of submersible motors replacing diesel engines. The traditional wells also started drying up. Under such a scenario large number of blocks was declared as dark zones. The Sri Ram Fibres (SRF) Pvt. Limited a corporate of repute established their chemical plant in Tijara block of Alwar district of Rajasthan. The SRF was charged with the responsibility to recharge ground water double the amount of water what they would extract for approval. SRF funded a Natural Resource Management (NRM) project in 35 villages situated around the plant with sharp focus on rainwater harvesting and ground water recharge. In this implementation model, corporate funding under Corporate Social Responsibility (CSR), the execution by a grass root NGO and evaluation, impact assessment and documentation by a professional group were the unique features. In a period from 2006 to 2023, 214 earthen dams were constructed to harvest rainwater from *Aravali* hills, 1850 ha of privately owned wastelands were leveled and terraced and put to crops adopting in situ rainwater harvesting. More than 450 fruit and fodder plants were planted on the reclaimed lands to improve the desiccating ecology of the project villages. The reservoirs of 35 representative dams were selected for detailed reservoir survey to find storage capacities, rain gauges were installed in seven study villages and also well observations were recorded from 40 observation wells to monitor the change in groundwater table. After the construction of dams in the upper areas almost all types of lands were leveled by the farmers and put to pearl millet and mustard crops which resulted in increased income and saving in water. The improved availability of green and dry fodder from reclaimed land reduced the livestock dependence on forest land and the number of cows and goats were reduced in favor of good breed buffaloes and farmers adopted dairying as a remunerative subsidiary occupation. The promotion of sprinkler and drip irrigation system resulted in 60 to 70 percent saving of irrigation water. Total cumulative groundwater recharge from 2006-07 to 2022-23 was 3262.11 ha-m. An oasis of green cover developed in the erstwhile barren lands and improved the overall ecology of the area. The ecosystem faced different climate change related challenges and an attempt was made to mitigate those challenges. The results of attempted innovations are presented in this paper.

Key words: *Aravali* hills, Climate change, Groundwater depletion, Rainwater harvesting, Wasteland development, Impact assessment

INTRODUCTION

The climate change impacts manifested in frequent floods and droughts, scarcity of water, high temperature and decreasing green cover are more discernable in the ecologically vulnerable ecosystems inhibited by resource poor communities. Several international and national agencies have highlighted such impacts of climate change and flagged the need of mitigation and adaptation measures. The global climate change cause rise in sea level, average temperature and precipitation and increase in frequency of floods, droughts, heat waves, melting of glaciers, and it is important for agriculture sector to adapt to such climate changes, particularly for food and water security (UNIPCC, 2007). Billions of people, particularly in developing countries, shall face shortages of water and food and greater risk of health and life as a result of climate change, and unfortunately they have fewer resources to adapt

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socially, technologically, and financially (UNFCCC, 2007). Baniston (2010) held that in the less developed countries, high population growth is linked to environmental degradation because local inhabitants tend to improve their resource base and economic level through over-exploitation of natural resources.

The International Panel on Climate Change (IPCC, 2013) projected the increase in number of hot-days, more frequent and intense heavy rains and change in rainfall pattern in Asia and specifically India. Any further delay in concerted anticipatory global action on adaptation and mitigation will miss a brief and be rapidly closing window of opportunities to secure a livable future for all (IPCC, 2022). The regions and people with considerable development constraints have high vulnerability to climate change. India is projected to be the most vulnerable to the climate change impacts (IPCC, 2023).

Some of the Indian researchers were equally concerned about the vulnerability of Indian ecosystems to climate change. According to Aggarwal (2008), India is one of the most vulnerable countries in the world to projected climate change as it is already experiencing changes in climate and the impacts include water stress, heat waves and drought, severe storms and flooding, and associated negative consequences on health and livelihoods. Nagavan and Anand (2018) held that the climate change is expected to have serious impact on India because the country rapidly extracting its natural resources thereby destroying its environment mostly due to urbanization, industrialization and economic growth.

Rajasthan is the largest state in India characterized by low and erratic rainfall, high air and soil temperature, intense solar radiation and high wind velocity which give rise to droughts and famines making local livelihoods highly vulnerable (Singh *et al*., 2010).

Due to over exploitation, the groundwater resources are depleting much faster than recharge in the drought-prone area of Rajasthan (CGWB, 2005; Nagraj *et al*., 2011 Jain *et al.*,2019). There was a six-fold increase in irrigated area and due to the fast depletion of groundwater, most blocks have been categorized as the dark and grey zones (Rathore, 2005; Bhan, 2009). According to Rathore and Verma (2013), the forest and pasture cover in districts of South Rajasthan has decreased due to excessive grazing and fuel wood extraction. Some areas of Alwar district contiguous to Haryana came under the influence of industry and colonization, which further aggravated the problem of groundwater depletion (Grewal, 2016). The fast expansion of irrigation led to unsustainable levels of groundwater depletion, a challenge for the sustainability of the agrarian economy in this ecosystem (Grewal, 2017).

Unique features of vulnerable Aravali hills ecosystem

The *Aravali* hill ecosystem, a part of the arid Thar Desert is one of the most water-stressed ecosystems of India, where the agrarian economy is constrained by climate change impacts. The low rocky hills were once covered with dense forest in the past and met the needs of fire wood and fodder of the community and helped in maintaining the delicate ecological balance of the ecosystem (Grewal, 2016). Large areas of community land were managed under an open access system. The hills were denuded of vegetation cover because of excessive fuel-wood extraction and over grazing by herds of cattle, goats, and sheep. The excessive biotic pressure has taken a heavy toll on the natural forest cover, resulting in severe land degradation with concomitant adverse environmental and socio-economic consequences impacting the quality of life of the inhabitants. What was a predominantly pastoral economy gradually transformed into arable farming with scant regard to low and erratic rainfall and limited ground water resources (Agnihotri and Grewal, 2011).

The entire region is presently facing acute water crisis in view of excessive loss of precious rainwater by runoff from bare hills and large scale extraction of ground water by ever increasing number of bore wells. In view of proximity to national capital region, farmers shifted to vegetable growing which needed large number of irrigations on light textured soils thus leading to overexploitation of under-ground water. The women literacy rate is less than 10 percent in many villages. Most men are involved in illegal mining as part of their secondary occupation. The drudgery of women is beyond description. The denudation of *Aravili* hills, illegal mining, fast depleting ground water ,low production potential, lack of money to invest on land improvement, lack of urge to adopt small family norms and get organized for common welfare are the host of problems which posed serious challenge for ecosystem rehabilitation and sustainable development (Grewal, 2021).

A corporate supported initiative

A leading chemical business company, Shri Ram Fibres Ltd. (SRF), established their plant in village Jiwana of Alwar district and was mandated by the Cental Groundwater Authority to recharge double the amount of water extracted as the plant was located in a water- stressed block. In view of this mandate, the company supported an integrated watershed development project in 35 villages of Tijara block in *Aravali* hills from 2006 to 2016, with a main focus on rainwater harvesting and groundwater recharge, wastelands development, planting of fruit and fodder trees, and empowerment of rural women under its Corporate Social Responsibility domain. The project was implemented with the help of a local NGO and technical support from the Society for Promotion and Conservation of Environment (SPACE) a professional group placed on board from day one.

Technology Package

- Community awareness and sensitization, organizing them into self-help groups (SHGs). Preparation of watershed based micro-plans and implementation in close partnership as per need, demand and technical feasibility.
- Since water scarcity mainly hinders economic development, harvest every drop of rainwater that runs off from barren hills during rains and forms gullies in wind- blown sandy tracts by constructing earthen embankments, locally called *paals*, varying in height from 6 to 12 meters, basically for groundwater recharge and flood control.
- Land leveling/field bunding of waste/under-utilized private lands on cost-sharing basis by forming clusters of farmers and putting them to productive use for food and forage security.
- Plantation of commercial fodder trees on bunds of reclaimed lands and along village roads and paths for ecological restoration and generation of cash flows.
- Organizing communities into SHGs, user groups to undertake construction of earthen dams, land development in clusters, and maintenance of plantations.

The company supported this project from 2006 till date with an added focus on de-siltation and renovation of old reservoirs and continued with hydrological and environmental studies. SPACE has regularly compiled data on designated indicators since 2008 till date. An attempt was made to insulate the area from the climate impacts under this integrated natural resource management project. The present paper presents the results of an impact assessment study conducted during 2023-24, taking data from seven study villages and some representative villages of the project.

MATERIALS AND METHODS

Rainwater harvesting for groundwater recharge

Out of 35 project villages of Tijara block, 7 were selected for detailed monitoring. The relevant information was compiled on different hydro-logical, land development, environmental and social aspects from 2007 to 2023. Ordinary rain gauges were installed in seven study villages and daily rainfall was recorded continuously from 2007 till date. Out of 214 earthen dams constructed (locally called *paals*), 35 were selected for detailed monitoring and evaluation. A detailed topographic survey of 35 reservoirs submergence area was carried out and depth versus storage curves were drawn. Vertical gauges were installed on reservoir slopes to measure the depth of water daily to find out amount of rainwater harvested by each rainfall storm. The loss of head indicated the amount of water loss due to evaporation and seepage. The daily pan evaporation data were collected from nearby Bawal Regional Research Station of Haryana Agricultural University Hisar. The daily evaporation from the pan was multiplied by 0.7 to get evaporation loss from the water body. By deducting evaporation from the total loss, the balance was treated as groundwater recharge. The volumes were worked out from depth versus storage curves. The data of 35 study *paals* was used to calculate the average groundwater recharge and extrapolated to the total number of *paals* in place each year to work out annual groundwater recharge. Regular well observations from 44 wells were recorded at fortnightly interval to study the groundwater fluctuations. This methodology was discussed earlier by Grewal (2021).

Waste lands development

In one of the important initiative, 1750 ha uneven and undulating lands was leveled under cost sharing system which prompted farmers to install tube wells and went for intensive irrigated agriculture. This provided food, fodder and economic security to the resource poor farmers. There was a large chunk of private uncultivated waste lands lying in the form of gullies and used as grazing grounds under a common access system. Poor farmers could not afford to level these lands. Moreover, the flood water from the *Aravalis* was discharged through these gullies which were deepening and widening. Due to this fear of soil erosion such lands were not brought under cultivation. The fear of floods was eliminated by the construction of earthen dams across most of these gullies. This prompted the land hungry farmers to invest on reclamation of written off private gullied lands. In recent last ten years, almost all the privately owned uneven and undulating uncultivated lands have been leveled by the farmers and put to crops. The construction of *Paals* was the necessary pre-requisite to take up the work of reclamation of waste lands. Land leveling and field bunding ensured in-situ conservation of rainfall and recharge of soil profile. A cluster approach was followed where *Paal* was made the nucleolus around which lands were developed and production improvement initiatives were started.

Commercial trees plantation

A condition was laid that farmers who receive financial support for waste land development shall have to plant trees on field boundaries, local paths and everywhere possible. Most farmers preferred aruneem (*Ailanthus excelsa) a* multipurpose fast growing fodder and commercial tree with market demand. Seedlings were provided free of cost to farmers from the project operated nurseries. Surveys revealed that by 2016, there were 4.5 lakh trees of aruneem in 35 project villages. The trees were defoliated in winter and used as green leaf fodder. The defoliated trees did not provide shade to winter crops and hence were compatible as an agro-forestry system. More than 75% plants were harvested by the farmers in project area. It was observed that approximately 90 percent harvested plants have gained new growth.

RESULTS AND DISCUSSION

The major climate challenge impacts addressed by the project includes denudation of *Aravali* Hills due to excessive grazing by livestock, flash floods from *Aravalis* cause severe soil erosion in private lands along the drainage lines, unsustainable ground water depletion with ever increasing number of tube wells, and excessive use of groundwater for irrigation on light texture sandy soils. This also included no income from private waste lands in land hungry agriculture. The reduction in groundwater recharge by a layer of silt on reservoirs surface of earthen dams was also a problem. The desiccating and harsh climate, faulty land use and the problem of poor farm economy were addressed. The description of these impacts addressed by the project and possible mitigation measures are discussed in the following sections.

Challenge 01: Denudation of Aravalis due to excessive grazing by livestock

Livestock rearing was part of livelihood system of poor people of the area. The communities were fully dependent on the forest for livestock grazing leading to denudation of *Aravali* hills. The project interventions improved the availability of green and dry fodder from the reclaimed lands and reduced the livestock dependence on forest land. This reduced the number of livestock and also changed the composition. The cows and goats were replaced by stall-fed buffaloes. In a typical project village Banjara, the total livestock population was reduced from 696 to 332 from 2006 to 2017 (Table 1).

Table 1. The livestock situation in a typical village of the project

Particulars	Before 2006	After 2017	Variation
Cow	279	66	-213
Goat	400	199	-201
Buffalo	13	67	+54
Camel	4	0	-4
Total	696	332	-364

The number of cows and goats were reduced in favor of good breed buffaloes and farmers adopted dairying as a remunerative subsidiary occupation. The production of milk in this village increased from 65 to 670 kg/day. The stall feeding also increased the availability of animal dung which women convert into dung cakes and use as fuel. Due to this, fuel wood pressure on the forest has also reduced.

Challenge 02: Flash flood from denuded Aravalis cause severe soil erosion

The flood water from the *Aravalis* was discharged through gullies and caused severe soil erosion in private lands of farmers. Due to this reason, private gullied areas were not brought under cultivation. Since 2014 earthen dams locally called '*Paals*' were constructed across major gullies emanating from *Aravali* hills for rain water harvesting due to which fear of floods was

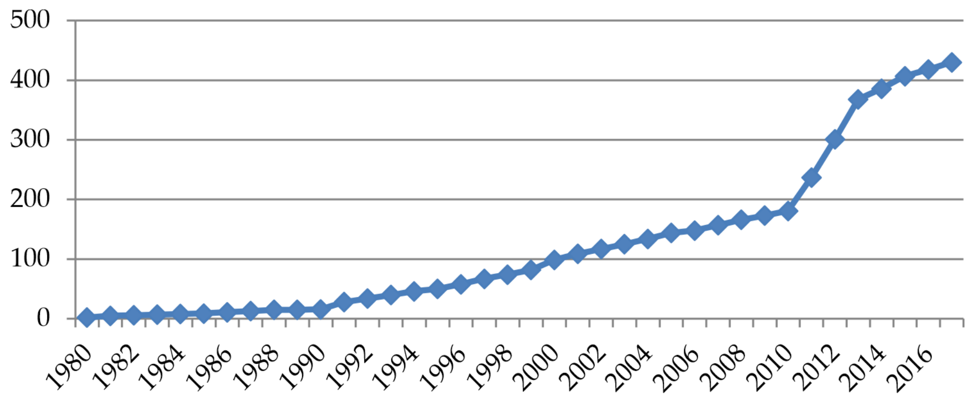

Fig. 1. No. of Bore wells in village Gualda from 1980 to 2017

eliminated. After the construction of dams in the upper areas almost all the privately owned uneven and undulating uncultivated lands in and around gullies have been leveled by the farmers and put to pearl millet and mustard crops

Challenge 03: Ground water depletion with ever increasing number of tube wells

As the irrigated agriculture expanded, large scale extraction of ground water by bore-wells continued unabated and reached an unsustainable level. This is indicated by data collected from Gualda village which shows that between 1980 and 2017, the number of tube wells increased from 5 to 430 and shallow tube wells had to be converted to submersible motors. The number of tube wells increased from 145 to 430 during the project period (Fig. 1).

As the waste lands were reclaimed with financial support from the project, farmers installed tube wells on the reclaimed land. This led to further jump in the number of tube well from 2010 to 2017. As a result, the water table has gone down from 9 to 26m. As the water table started going down, the horse power of the electric motors has gone up from 7.5 to 10 hp and shallow tube wells were converted to submersible motors at a huge cost whose number increased from 4 to 112 from 2006 to 2022 in Gotoli village. Now all the tube wells are electricity operated with submersible motors (Fig.2).

The rise in the number of submersible motors coincided with the start of waste land development.

Rainfall is the only source of recharge in the area and when rainfall is low, water table goes down but when rainfall is good, the deficit is recouped to some extent. Shakla, P. and Narayan, (2020) made similar observations on fluctuations of groundwater table in the state of Rajasthan.

There was consistent drop in groundwater levels from 2007 to 2023 in bore wells of Gotoli and Gualda villages (Fig. 3).

Efforts were made to recharge the depleting groundwater by the construction of earthen dams for rainwater harvesting to recharge groundwater. Total cumulative groundwater recharge from 2006-07 to 2022-23 was 3262.11 ha-m or 32621100 kiloliters as shown graphically in Fig.4.

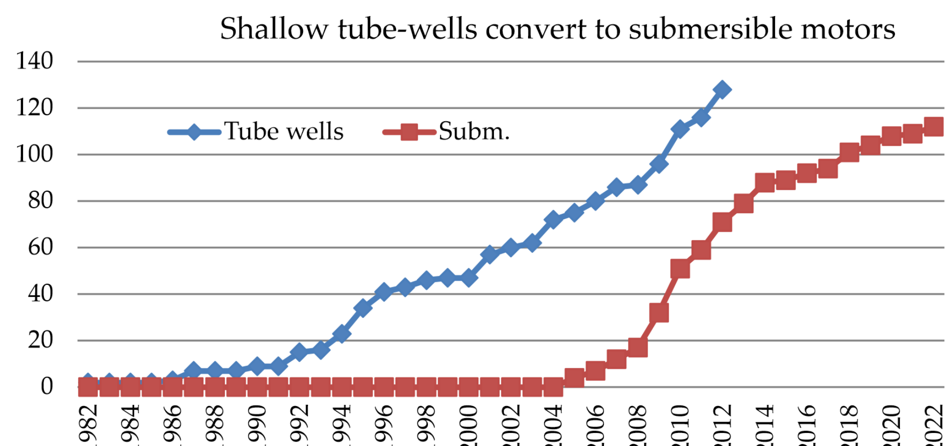

Fig. 2. Number of tube-wells and submersible motors in different years

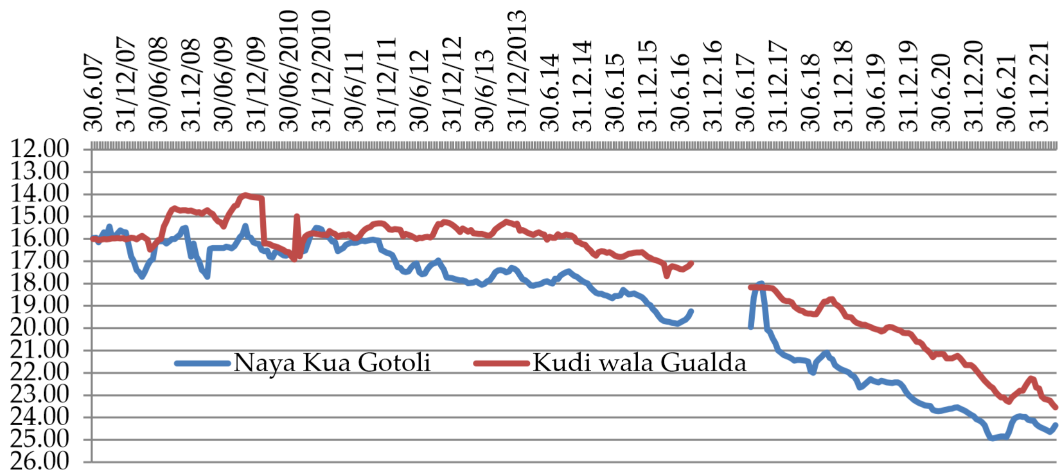

Fig. 3. Groundwater levels from 2007 to 2023 in bore wells of Gotoli and Gualda villages

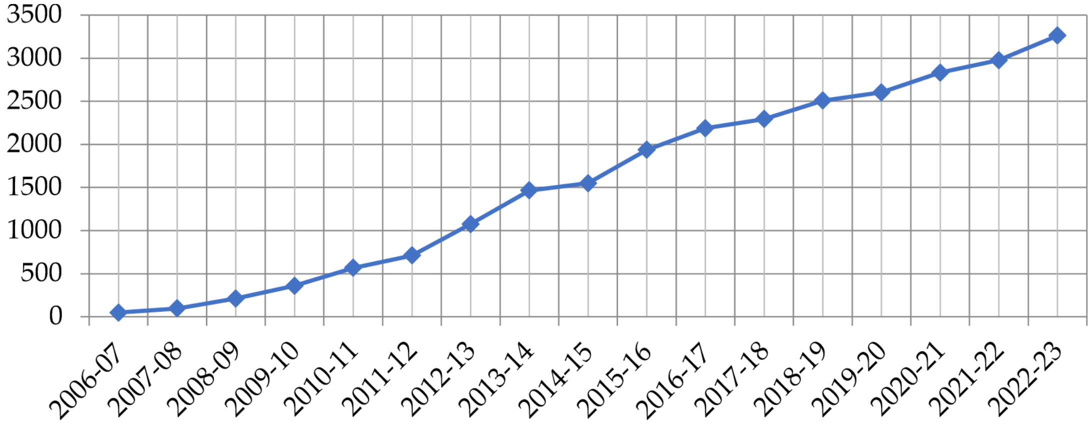

Fig. 4. Total cumulative recharge (ha-m)

Inspite of intensive rainwater harvesting for groundwater recharge, the water table went down because of ever increasing number of bore wells. Possible sollutions are suggested at the end.

Challenge 04: Excessive use of groundwater for irrigation on light textured sandy soils

Due to high seepage of irrigation water on light textured sandy soils coupled with higher temperature, very frequent irrigations are required which deplete the scarce groundwater. The sprinkler and drip irrigation system was promoted by the project which saved lot of irrigation water and labor cost. There was 60 to 70 percent saving of irrigation water and area under drip irrigation is increasing fast.

Challenge 05: No income from private waste lands in land hungry agriculture

There was a large chunk of private uncultivated waste lands lying in the form of gullies and used as grazing grounds. Poor farmers could not afford to level these lands. Moreover, the flood water from the *Aravalis* was discharged through these gullies and could wash away the leveled lands. Due to this fear such lands were not brought under cultivation. However, the fear of floods was eliminated by the construction of earthen dams across these gullies. The cash generated from 1750 ha land leveled earlier prompted them to reclaim these written off lands located around the gullies. In recent last ten years, almost all the privately owned undulating uncultivated lands have been leveled and put to crops.

The construction of *Paals* was the necessary pre-requisite to take up the work of reclamation of waste lands because without control of run-off and flooding, there was danger of leveled land getting washed away or bunds breached. Land leveling and field bunding ensured in-situ conservation of rainfall and recharge of soil profile. A cluster approach was followed where *Paal* was made the nucleolus around which lands were developed and production improvement initiatives were started.

Table 2. Analysis of cost and returns from a reclaimed gullied land in village Gotoli

Particulars	Wheat			Mustard			Bajra			Total Rs
	Qty./ ha	Rate Rs/q	Income Rs.	Qty./ ha	Rate Rs/q	Income Rs	Qty./ ha	Rate Rs/q	Income Rs	
Grain	40	1800	72000	16	4400	70400	20	1800	36000	178400
Fodder	40	500	20000	-	-	-	36	250	9000	29000
Fuel wood	-	-	-	L/s	L/s	8400	-	-	-	8400
Total output	-	-	92000	-	-	78800	-	-	45000	215800
Input cost Rs.			67400			46800			37200	151400
Net profit (per ha)			24600			32000			7800	63400
B-C ratio			1.36			1.68			1.21	
Net area (ha)			0.75			8.75			9.50	
Net profit Rs			18450			280000			74100	372550

A case study of Dhundhalia wali *paal* in Gotoli village is presented**.** This *paal* was constructed in 2007 in foot of *Aravali* hills in village Gotoli having catchment area is 75.85 ha. *Paal* was made the nucleolus around which waste lands were developed by the farmers and it was mostly used as grazing lands. A total of 9.50 ha of waste land above and below the *paal* was leveled and brought under cultivation by 9 farmers and started growing mustard and wheat in *rabi* and *bajra* in *kharif*. The financial analysis indicated a net profit of Rs 372550/ year by 9 farmers (Table 2).

In the last 10 years 760 ha lands was converted into lush green cover in seven study villages. In Gotoli village alone, 65 ha of such gullied lands were leveled which produced 163 tons of wheat and147 tons of mustard providing a net income of INR 12,02,900/year annually or Rs18500/ha. An oasis of green cover developed in the erstwhile barren lands and improved the overall ecology of the area. Additional food and forage production added to food security. The improvement in the economic status, social pride, self-employment, urge to progress and reinvest in land based assets and activities were observed. The number of tractors increased from 20 to 37, bikes from 55 to 135 and car from 3 to 7 in a period of fourteen years in Gole village. The families have been put on a trajectory of growth.

Challenge 06: Reduction in groundwater recharge by a layer of silt on reservoirs surface

Due to the deposition of a fine layer of silt on the surface of reservoirs, the soil pores were chocked leading to prolonged storage of water which results in less groundwater recharge and more evaporation loss of rainwater. In order to solve this problem, bigger *paals* were de-silted and renovated every year.

The de-silting and slope repair work was started during the year 2019-20 and out of 146 functional *paals*, 37 were de-silted up to the year 2023-24. The hydrological data collected from such de-silted *paals* clearly indicated substantial increase in ground water recharge. The high storage loss due to fast percolation of stored water indicated increase in ground water recharge. The details of percolation rate before and after de-siltation is given below Table 3.

In case for example, before de-silting, the water level reached 1.38m which after 29 days reduced to the level of 0 thus registering a loss of 1.38m or 4.75 cm/day. Data presented graphically in Fig. 5.

The percolation rate increased from 4.75to 18cm /day indicating higher rate of recharge after de-siltation.

Table 3. Percolation rates in a typical *paal* before and after de-siltation

Before de-siltation			After de-siltation			Deference cm/day
Water level in reservoir (m)	No. of storage days	Loss of water cm/day	Water level in reservoir (m)	No. of storage days	Loss of water cm/day	
1.38	29	4.75	1.80	10	18	13.25

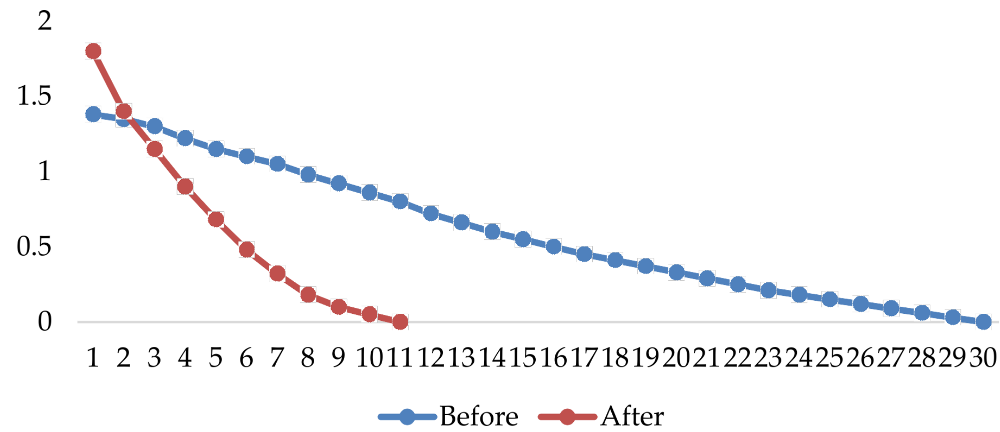

Fig. 5. Percolation rate after and before de-siltation in Adi ka moda wali paal, 2022-23

Challenge 07: Desiccating and harsh climate

Harsh climate, low and erratic rainfall, thirsty and hungry sandy soils characterize the bio-physical setting of this ecosystem. Growing of fruit and fodder plants as such was not a normal practice in the area because of scarcity of water and desiccation environment. The project attempted to develop tree cover on the reclaimed waste lands, along roads and paths. Nursery raised plants were given to farmers for planting. Over the years 4.5 lakh aruneem (*Ailanthus excelsa*) trees and fifty thousand fruit plants got established on the land of 2,456 families in 35 villages

The aruneem trees were considered as bank deposit by the farmers. Branched were pollarded in winter and used as green leaf fodder for goats and branches for fuel wood. After six to seven years trees were harvested and money thus receive was used to pay loans, purchase of farm implements and bikes, housing and marriage of children. Fortunately the harvested trees have again sprouted to provide second crop in due course of time. In Gole village of the project out of 15100 aruneem plants planted, 6103 survived and 3385 plants have been sold by 47 farmers for Rs.2395700/-. The average income was 50972/- per family with average price of Rs.708 / trees.

Several families shifted their residences to reclaimed lands for effective watch and ward and planted shade trees along settlements. In Gole village alone 105 different types of shade trees have been planted during the last couple of years. In last 10 year, 84 families shifted their residence and raised 1744 fruit and fodder plantation around the new hamlets in seven study villages. In addition more than 400 new plants have come up on *paal* slopes in Gole village. In this way an oasis of greening has developed in the otherwise barren landscape.

Challenge 08: Faulty land use system

Pearl millet in *kharif* and mustard in *rabi* were the main rain-fed crops before the irrigation system got introduced in this area. Irrigation gradually introduced wheat, cotton, and vegetable crops, especially summer onion because of their profitability. These high value crops needed large number of irrigations and this resulted in lowering of water table to unsustainable levels. As the water crisis deepened, favorable trend in land use was noted in recent years. In a typical Gole village, the area under wheat and barley decreased substantially with simultaneous increase in area under mustard during *rabi* season. Similarly area under cotton and summer onion drastically decreased with simultaneous increase in area under pearl millet (Table 4).

Similar situation was reflected in water use both in *rabi* and *kharif* seasons over the years. The overall water requirement decreased from 224.312ham in 2021 to 158.175 in 2023 ham with the increase in area under mustard and pearl millet. Pearl Millet and Mustard are most suitable crop for the region in terms of economic benefits as well as checking falling groundwater table (Tarasarthy *et al*., 2021).. Since 2023 was declared as international year of millets, the profile of Pearl Millet has improved and it holds lot of promise under low rainfall and sandy soils. Tara *et al.* (2021) advocated that pearl millet being a climate resilient crop is important to mitigate the adverse effects of climate change and has the potential to increase income and provide food security to the farming communities inhibiting the eco-sensitive arid regions. They desired that the nutrient and climate resilient attributes of pearl millet should be exploited.

Table 4. Area under Rabi and Kharif crops from 2021 to 2023 and water requirement

Name of crops	Area in (ha)			Require of water per ha/ha-m			Total water requirement (ha-m)		
	2021	2022	2023	No. of irrigations	Depth of irrigations in (cm)	Requirement of water m	2021	2022	2023
Rabi season									
Wheat	210.75	156.8	150.0	7	5	0.35	73.762	54.862	52.5
Mustard	264.5	318.5	362.0	3	5	0.15	39.675	47.775	54.3
Barley	57.5	47.5	35.5	5	5	0.25	14.375	11.875	8.875
Total	532.75	522.8	547.5				127.812	114.512	115.675
Kharif season									
Cotton	60.0	20.0	10.0	5	5	0.25	15	5	2.5
Bajara	350.0	415.3	480.0	1	5	0.05	17.5	20.76	24
Onion	80.0	39.5	20.0	16	5	0.8	64	31.16	16
Total	490.0	474.8	510.0				96.5	56.92	42.5
Gross total	1022.75	997.6	1057.5				224.312	171.432	158.175

Challenge 09: Poor farm economy

There were discernable changes in farm economy. The farmers started replacing scrub animal like goats and cows with stall fed buffaloes of Murrah breed as keeping of few better breed buffalo was more remunerable. This happened basically because of the availability of dry and green fodder from the irrigated reclaimed lands. The young boys started going to the schools and not for taking livestock for grazing in the forest land. This reduced biotic pressure on *Aravali* hills. The number of girl students increased from 11 to 42 percent in Gole village. The increase in income from reclaimed lands, sale of trees and milk caused changes in terms of standard of living. The investment on education, housing, health care, clothing, nutrition, bikes, religious ceremonies have increased. The improvement in the economic status, self-esteem, social pride, self-employment, urge to progress and reinvest in land based assets and activities were observed. The number of tractors increased from 20 to 37, bikes from 55 to 135 and car from 3 to 7 in a period of fourteen years in Gole village.

CONCLUSION

The project has distinctive features which include focus to a most vulnerable area, corporate funding, implementation by a grass root NGO, systematic data collection, monitoring and evaluation by a professional group. The end result was a mix of success and failures. There was grazing control in *Aravali* hills as indicated by replacing cattle and goats by stall-fed buffaloes. The menace of floods was largely controlled by the construction of 214 earthen dams. Land leveling of barren unproductive lands ensured increased food grains and forage production and generated cash flows. The ecological restoration by plantation of 5.0 lakh fodder and fruit trees provided handsome returns to farmers which were used for payment of loans, purchase of farm equipment, installing sprinkler and drip irrigations, better housing and health care and education. The regular de-silting and renovation of reservoirs resulted in groundwater recharge curtailing evaporation loss from silted reservoirs.

The dilemma of lowering of water table by ever increasing number of bore wells continues to persist. The positive indications included saving of 60 to 70 percent irrigation water by promotion of sprinkler and drip irrigation. Secondly was the increase in area under pearl millet and mustard requiring less number of irrigations against wheat, cotton and vegetables particularly summer onion. Lastly, plantation of aruneem, increase in number of trees on earthen dam slopes, along new settlements combined together created an oasis of greenery thus reducing desiccating effects of hot winds. Moreover, green crop cover of crops in reclaimed gullies contributed to ecological restoration. The improvement in farm economy is indicated by a number of parameters and communities were placed on a trajectory of growth.

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