Enhancing groundwater recharge and water use efficiency in drought prone Bundelkhand region

ICRISAT
INTERNATIONAL CROPS RESEARCH INSTITUTE FOR THE SEMI-ARID TROPICS

IDC ICRISAT DEVELOPMENT CENTER

केकृवाअनुसं CAFRI

THE Coca-Cola FOUNDATION

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Background

The Bundelkhand region of central India is a hotspots of water scarcity, land degradation and poor socio-economic status.

The region experienced severe drought conditions in the last six years out of ten years. More than 80% open wells dried up soon after monsoon season due to deficit rainfall and poor groundwater recharge. In the absence of drinking water and livelihood opportunities, a large proportion of rural population gets migrated to nearby cities in search of livelihood.

The Parasai-Sindh watershed, comprising three villages and covering nearly 1,250 ha, was selected for developing a benchmark site in Jhansi district. From 2012 onwards, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) along with national partners ICAR-CAFRI (Central Agro-Forestry Research Institute, Jhansi), district administration, government of Uttar Pradesh and local community started implementing watershed interventions in this area as a pilot watershed with financial support from Coca Cola India Foundation.

As an entry point, community mobilization and rapport building was achieved through formation of watershed committee under the regular support and guidance of CAFRI and ICRISAT.

Objectives

- To enhance water availability in the three villages through rainwater harvesting and recharging of the wells through water harvesting structures.
- To enhance water use efficiency and agricultural productivity through agroforestry based improved management of land and water resources.
- To establish a model site for learning.

Main Interventions

In pilot villages:

The main interventions of the project villages were undertaken:

- Rejuvenation and repair of the old “haveli” in Parasai village, which has capacity to harvest nearly 75,000 m^3 surface runoff.
- Construction of 9 check dams, 3 nala plugs and 1 farm pond which has all together created 40,000 m^3 storage capacity of runoff harvesting
- Earthen bunding in 50 ha area has ensured reduced soil erosion and better water retention.
- Improved crop and water management practices resulting in enhanced crop yields by 50 to 125% over the farmers’ practice and increased incomes of nearly ₹50,000 ha^{-1} thru increased cropping intensity by 30 to 50%.
- Nearly 200 ha fallow land was brought under cultivation during Rabi enhanced cropping intensity and total crop production significantly.

Structures

The hydrological monitoring showed that nearly 250,000 cubic meter of water is harvested annually in storage structures which enhanced groundwater level by 2 to 5 meter, with an average of 2.5 meter compared to base line status (before interventions).

Cropping intensity increased by 30-50%. For example, post-intervention, for the first time in history, farmers at upstream sites were able to cultivate wheat in more than 200 ha land, with increased groundwater availability. This resulted in crop intensification and extra source of income.

Increased water yield in open wells facilitated farmers to complete their irrigation operation in few days as they can pump water for 8-10 hours per day and therefore enhanced labour use efficiency. In addition, *in -situ* practices such as Field bunding was undertaken to conserve soil and moisture in about 50 ha land with the provision of constructing safe water outlet structure for flood management.

Cost-effective Checkdam (CD) No./Nallah plug	Catchment area (ha)	Volume (m^3)
CD-1 (*Haweli*)	51	75000
CD-2	95	12000
CD-3	310	2000
CD-4	350	3000
CD-5	478	2000
CD-6	550	4000
CD-7	700	3500
CD-8	950	4000
CD-9	25	3000
CD-10	42	2000
Outlet	1246	-
NP-1	5	700
NP-2	10	800
NP-3	13	1000
Farm Pond	5	2000
Total		**115000**

Crop productivity and diversification

Productivity of post-monsoonal crop especially wheat has increased by 30-50% after the watershed interventions. Wheat yield before the watershed interventions was in the range of 1,500-1,800 Kg ha^{-1}. Before watershed intervention, despite the good establishment of crop, there was a high chance of crop failure or poor production, as depleted water resources by the end of Jan-Feb resulted in water shortage.

After the implementation of the watershed program, farmers on an average started harvesting wheat yield ranging from 2,000-3,200 kg ha^{-1} (average 2600 kg ha^{-1}) which has made significant improvement in their income and livelihood.

Nearly 200 ha fallow area is brought under cultivation in Rabi season

Further, farmers have shifted from low-water requiring crops to high yielding, high-value crops. For example, there is huge shift in the cropping system, from chickpea to wheat and barley during *Rabi* (post rainy) and vegetables in summer.

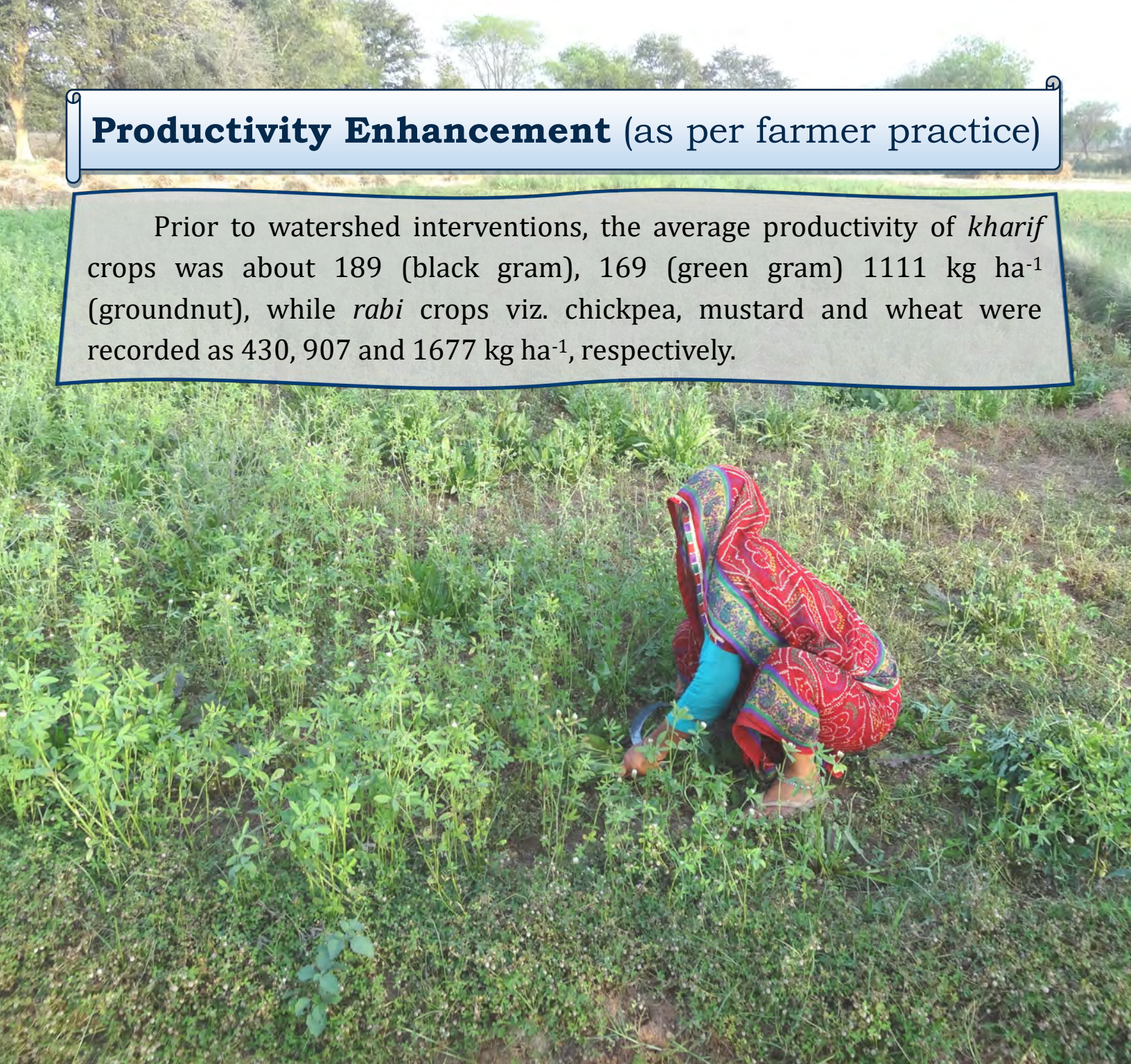
Livestock Rearing

Fodder availability has drastically increased and therefore milch animal population also increased by 30% (950 to 1300) within the first three years of the project period. Large scale surface and groundwater availability reduced the drudgery of men and women farmers in the villages. Easy access to drinking water for domestic animals has resulted in an average increase in milk yield per animal by two and half liter or more.

Moreover *in-situ* soil and water conservation practices have been promoted. Fodder grasses such as Napier grass cultivated on field bunds for addressing fodder scarcity. Agro-forestry is being strengthened by promoting teak plantation (teak) on farm bunds and ber budding.

Productivity Enhancement (as per farmer practice)

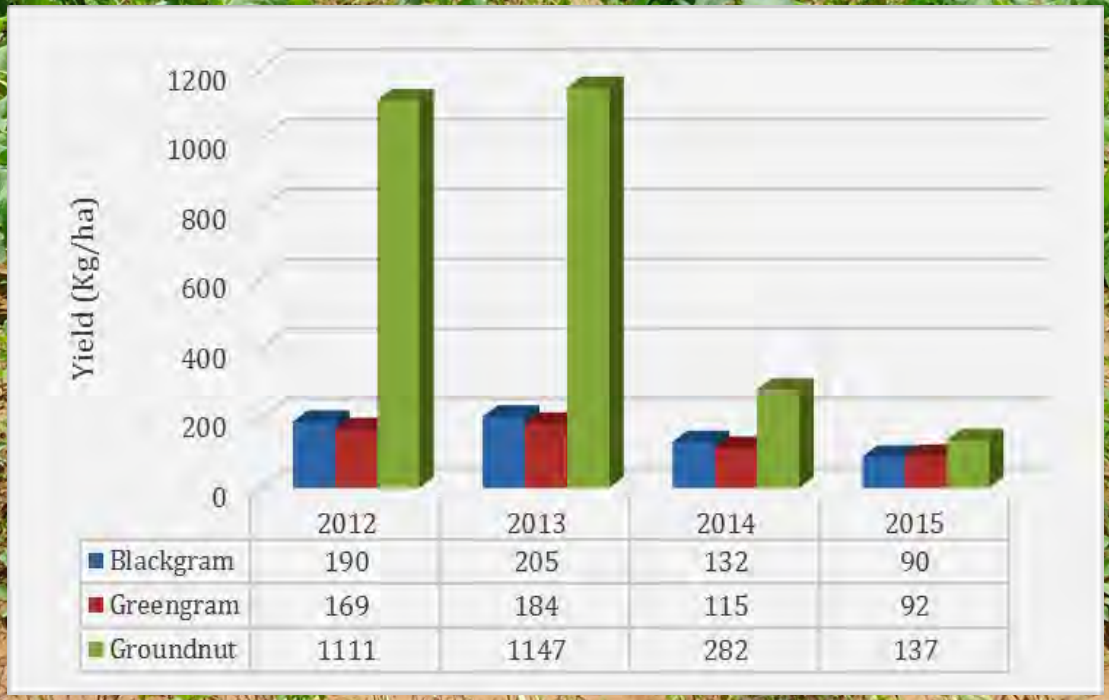
Prior to watershed interventions, the average productivity of *kharif* crops was about 189 (black gram), 169 (green gram) 1111 kg ha^{-1} (groundnut), while *rabi* crops viz. chickpea, mustard and wheat were recorded as 430, 907 and 1677 kg ha^{-1}, respectively.



During *kharif* season (2013) due to normal monsoon, an average increase of 7.7 (black gram), 9.0 (green gram) and 3.2 % (groundnut) was recorded, however during subsequent years (2014-2015), due to erratic rainfall (drought years), the productivity of *kharif* crops has declined significantly (as *kharif* crops are totally rain dependent in the area).

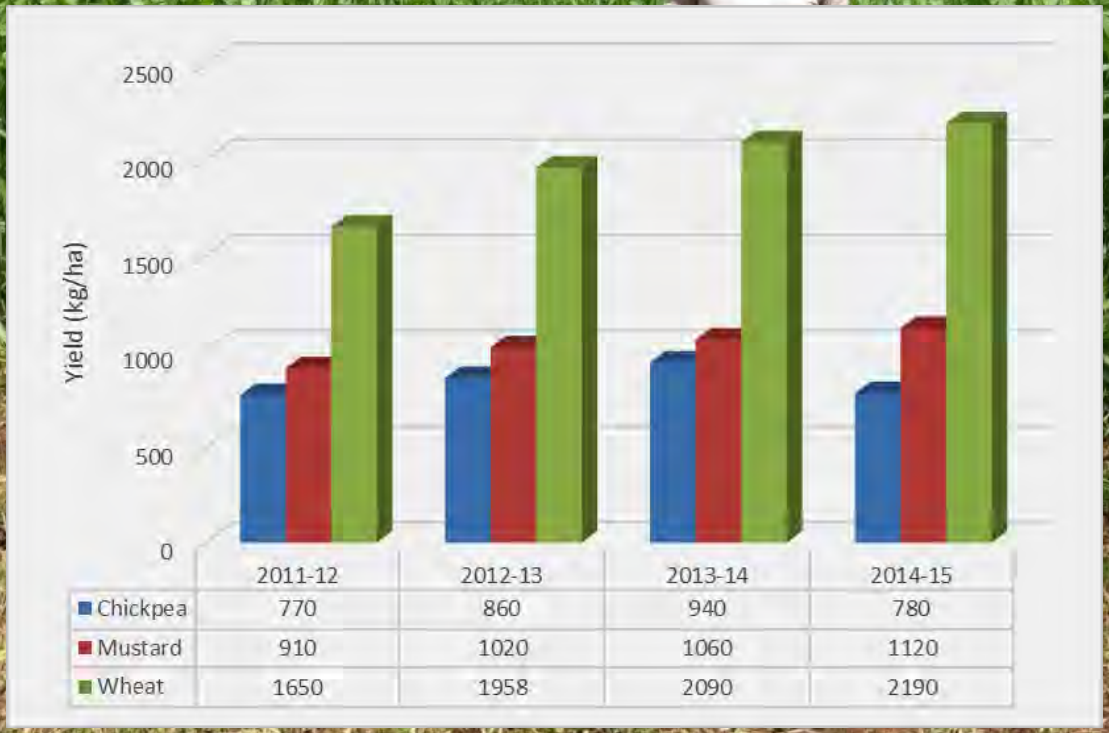
With the soil & water conservation measures during 2012-13, the productivity of *rabi* crops has increased substantially. The average increase has been recorded in the range of 1.4-20.91 % (chickpea); 12.3-16.2 % (mustard); 18.7-32.7% (wheat).

Average productivity of *kharif* crops



	2012	2013	2014	2015
Blackgram	190	205	132	90
Greengram	169	184	115	92
Groundnut	1111	1147	282	137

Average productivity of *rabi* crops



	2011-12	2012-13	2013-14	2014-15
Chickpea	770	860	940	780
Mustard	910	1020	1060	1120
Wheat	1650	1958	2090	2190

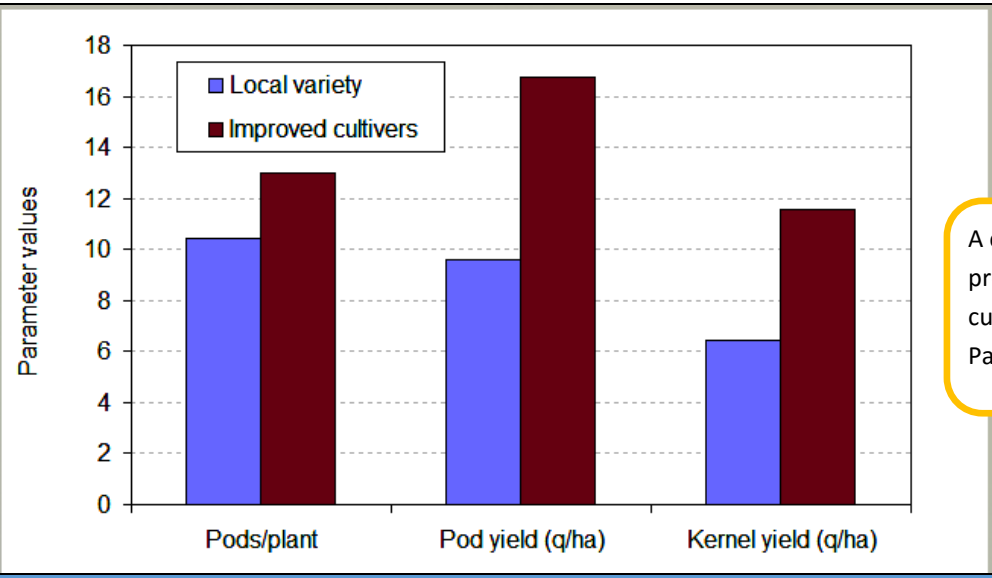
Use of micronutrients and improved cultivars

The yield gap analysis undertaken by the ICRISAT, revealed that the soils were deficient in essential nutrients as 50-90% of the farmers' fields were found deficient in sulphur, zinc and boron.

	EC ($ds\ m^{-1}$)	Exch-K ($mg\ kg^{-1}$)	Ols-P ($mg\ kg^{-1}$)	Org-C (%)	Avail-Zn ($mg\ kg^{-1}$)	Avail B ($mg\ kg^{-1}$)	Avail-S ($mg\ kg^{-1}$)
AVG*	0.16	83	11.12	0.51	0.75	0.23	5.47
STD	0.10	60	6.96	0.19	0.39	0.11	3.00
Max	0.54	335	36.00	1.10	2.50	0.64	19.95
Min	0.04	25	1.20	0.22	0.22	0.10	1.85
* Total 80 soil samples were collected from top 0-15 cm depth							
Table : Soil fertility status in selected villages							

In this context, farmers' participatory trials were undertaken during *kharif* 2011 to demonstrate the impact of micronutrients (Zinc and Boron) application on groundnut yield. Farmers contributed 50% of the cost on Agribor (B) and Zinc Sulphate (ZnSO4) and local groundnut variety. It was observed that application of B and Zn increased groundnut yield by 15-20%.

Table: Impact of balanced micronutrient application on groundnut crop during *Kharif* – 2011	
Treatment	**Pod yield (kg ha^{-1})**
Groundnut + RDF* + Agribor + Zinc Sulphate	1825 (21%)± 325*
Groundnut + RDF	1510±212
RDF: Recommended Dose of Fertilizers; Groundnut variety: local; * figures in parenthesis are % increase over control.	



A comparison of groundnut productivity among improved cultivars and local variety in Parasai Sindh watershed

Table: Yield difference in Groundnut (local and improved cultivar) and Soybean with the use of agribor during *Rabi*-2012-13 and *Kharif* (2013)		
***Kharif*-2013**	**Crop variety**	**Pod Yield (t ha^{-1})**
Groundnut	ICGV 9346 with agribor	1.90
	ICGV 9346 without agribor	1.84
	Jhumku (Local) with agribor	1.48
	Jhumku without agribor	1.42
Soybean		Av. Seed yield (tha^{-1})
	PUSA 9712 with agribor	0.72
	PUSA 9712 without agribor	0.65

Participatory crop demonstrations

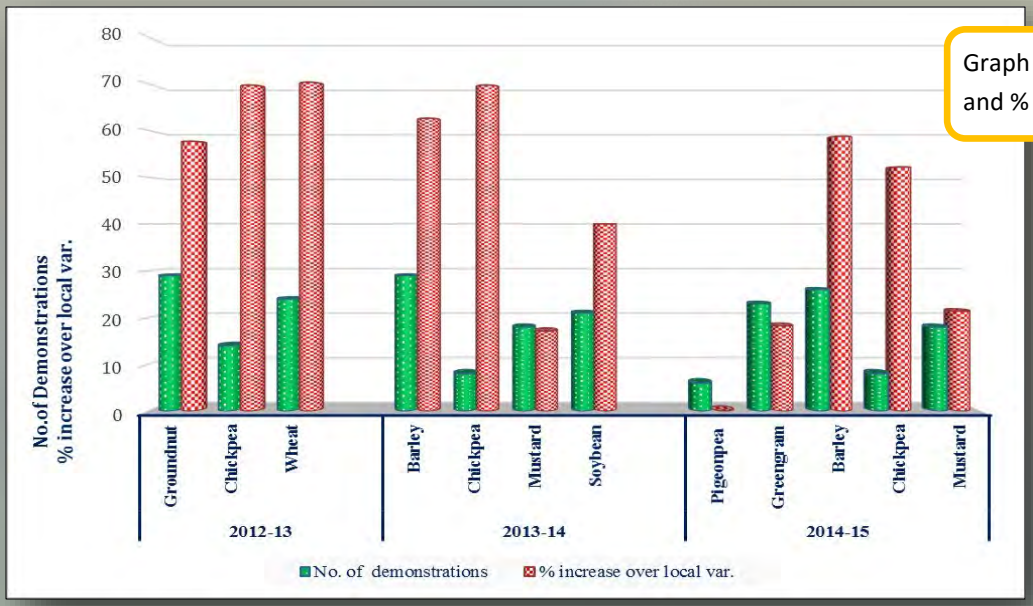
A total of 61 (Parasai), 125 (Chhatpur) and 38 (Bachhauni) participatory demonstrations conducted by staff from ICAR-CAFRI and ICRISAT were laid out at farmers' fields in the watershed area with improved varieties, in which about 7500 kg seeds of improved varieties were sown. Farmers contributed 50% of the cost of varieties sown as crop demonstration. An average increase of 57.7% (groundnut), 69.7% (chickpea), and 70.3% (wheat) (2012-13); 62.6% (barley), 69.7% (chickpea), 17.1% (mustard) and 40.0% (soybean) (2013-14); 18.2% (green gram), 58.8% (barley), 52.2% (chickpea) and 21.4% (mustard) was recorded in the watershed area. The wheat crop was most benefitted with the watershed intervention.

			Demonstration (No.) in different villages					
Year	**Crops**	**Varieties introduced**	**Parasai**	**Chhatpur**	**Bachhauni**	**Total No. of demonstrations**	**Av. grain or pod yield (kg ha^{-1})**	**% increase over local var.**
2012-13	Groundnut	ICGS 5, ICGV 350, ICGV 86015, ICGV 8784, ICGV 91114, ICGV 9346, and TAG 24, Shivpuri and Jhumku (local)	13	14	2	29	1750	57.7 (1111)
	Chickpea	JG 11, JG 130, ICCC 37		10	4	14	1350	69.7 (793)
	Wheat	HI 1531, HI 1544, HI 1418, HI 1479	9	13	2	24	2860	70.3 (1677)
Total			**22**	**37**	**8**	**67**		

Year	Crops	Varieties introduced	Demonstration (No.) in different villages			Total No. of demonstrations	Av. grain or pod yield (kg ha^{-1})	% increase over local var.
			Parasai	Chhatpur	Bachhauni			
2013-14	Barley	RD 2552	9	20		29	2400	62.6 *(7039)*
	Chickpea	JG 11, JG 130		4	4	8	1400	69.7 *(489)*
	Mustard	Maya	4	8	6	18	1200	17.1 *(7675)*
	Soybean	PUSA 9712	1	12	8	21	720	40.0 *(170)*
Total			**14**	**44**	**18**	**76**		
2014-15	Pigeonpea	ICPL 85063 (Lakshmi), ICPL 88039	3	3		6	760	*
	Greengram	Samrat	12	9	2	23	160	18.2 *(798)*
	Barley	RD 2552	6	20		26	2240	58.8 *(7076)*
	Chickpea	JG 11, JG 130		4	4	8	930	52.2 *(276)*
	Mustard		4	8	6	18	990	21.4 *(471)*
Total			**25**	**44**	**12**	**81**		

Figures in the parenthesis shows the average yield of local varieties with local practices

* Farmers in the area prior to watershed interventions did not take up pigeonpea crop



Graph depicting no of crop demonstrations and % increase over local varieties

Agroforestry Interventions

Through agroforestry interventions in watershed a total of 22,260 (5,377 fruits and 16,833 MPTs) seedlings of different tree species were planted in on field bunds .

Also, more than 150 farmers planted teak on the field boundary. Survival of different species varied from 32% to 95% by the end of 2015. Apart from this, till now 2100 *desi ber* trees were budded with improved varieties with more than 80% survival.

Improving Nutrition

As many as 67 household have planted guava, citrus, pomegranate in their homestead with survival more than 90%. Plantation in homestead are meeting nutritional requirement of the households.

Income-generating activities

Farmers were trained to prepare vermicompost through hands on training at Ganeshgarh village, Babina, Jhansi. Compost were prepared from locally available materials (crop straw, biomass and cow dung) . In the year 2012, farmers constructed 12 pits at different locations in watershed and produced nearly 40-50 tons of vermicompost.

Also training on lac cultivation, gum and resin extraction techniques, fisheries, were provided in order to develop alternative livelihood support systems in the watershed area.

Tangible Benefits in Parasai-Sindh Watershed

- Runoff and soil loss reduced by more than 50% in treated watershed as compared to untreated watershed.
- Rainwater harvesting capacity of 1,15,000 m^3 has been created and there is 2-3 times of filling of structure during rainy season.
- Water table in Parasai-Sindh watershed increased by 2.5 m on an average, as compared to pre-watershed interventions. Increase in water table is found as high as 4.0 m near stream locations and 2 m at upstream areas.
- Surface water in *nallah* is available throughout the year against four months only in untreated area.
- Cropping intensity in treated watershed has increased from 150 % (pre watershed interventions) to 200%.
- About 40-200 ha permanent *rabi* fallow in the upper reach has been brought under cultivation due to improved yield of open wells after rejuvenation of *Haweli* system and other water harvesting structures.
- General productivity of major crops increased up to 33% as compared to baseline productivity during rainy season and by 50-100% during *rabi* (p-rainy) season.

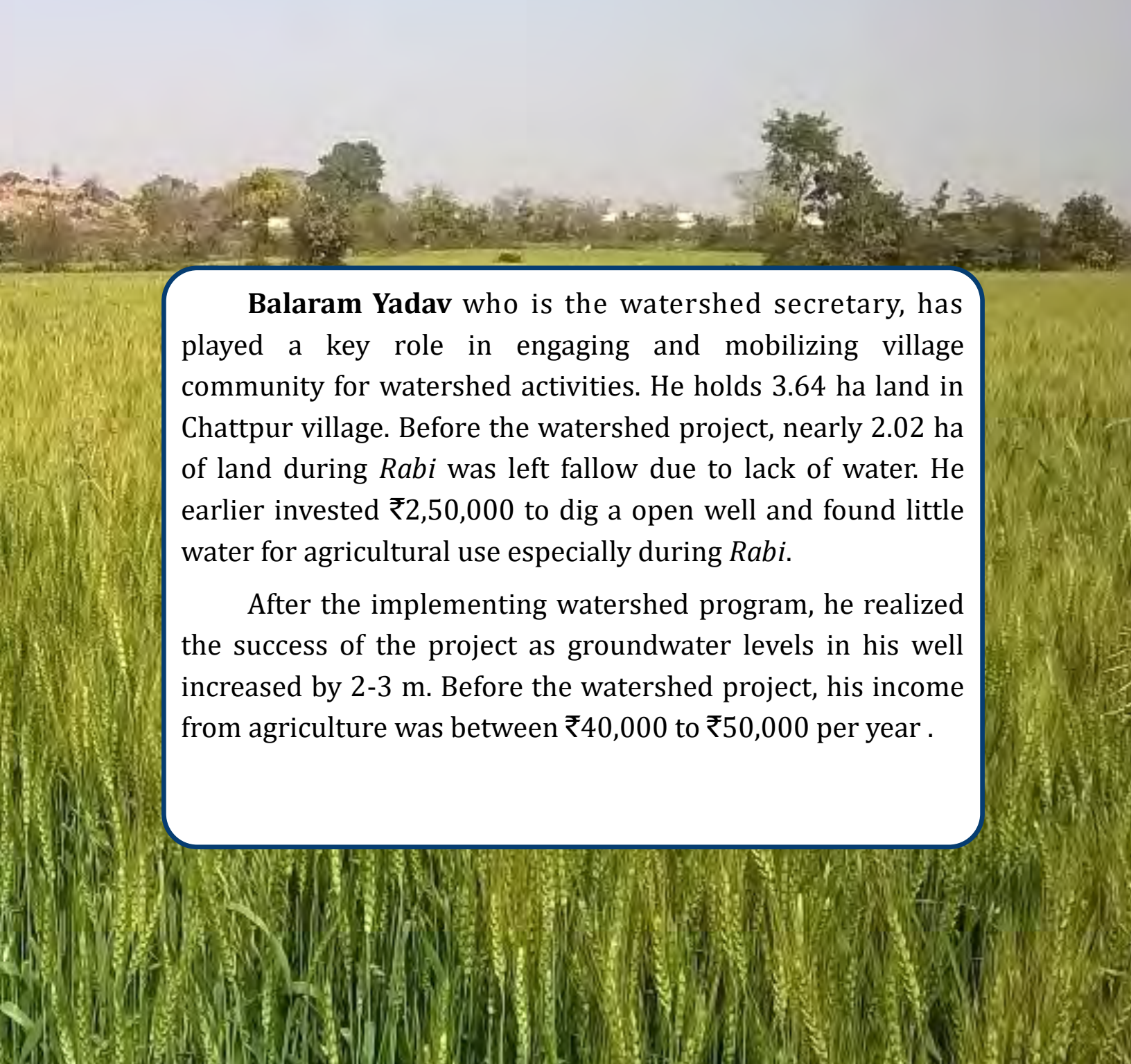
Tangible Benefits in Parasai-Sindh Watershed

- Cost of irrigation to wheat crop (90 % of cropped land) reduced by ₹ 6000-12000 ha^{-1}.
- No. of livestock F950 to 1300) and its productivity has substantially increased.
- Area under improved pasture and cultivated fodder has increased from 5 ha to 60 ha.
- About 2100 *desi-ber* plants have been budded with improved cultivars.
- Two SHGs of landless have been constituted and their livelihood has been strengthened through "*Dona"* making machine.
- During implementation phase, about 10,000 human days employment was created through construction activities and adoption of agroforestry interventions. Now, 17000 additional human days are created annually due to increased cropping intensity, crop demonstrations, agroforestry interventions, etc.
- Migration in search of livelihood has been reduced from the watershed area
- Even during continuous drought of two years (2014 & 2015), none of the farmers have migrated from the watershed in search of livelihood opportunities.

Success Stories

Increased yield in wheat and groundnut in Chattpur village after watershed program

After the watershed interventions, wheat yield doubled and he could able to cultivate wheat in entire 3.64 ha land. In the year 2013-14, he could harvest 5000 kg of wheat from 3.64 ha area and received a net income of ₹75,000 from wheat alone.



Balaram Yadav who is the watershed secretary, has played a key role in engaging and mobilizing village community for watershed activities. He holds 3.64 ha land in Chattpur village. Before the watershed project, nearly 2.02 ha of land during *Rabi* was left fallow due to lack of water. He earlier invested ₹2,50,000 to dig a open well and found little water for agricultural use especially during *Rabi*.

After the implementing watershed program, he realized the success of the project as groundwater levels in his well increased by 2-3 m. Before the watershed project, his income from agriculture was between ₹40,000 to ₹50,000 per year .

By cultivating groundnut during *Kharif*, the farmer (**Balaram Yadav)** received total groundnut production of 5000 kg from 3.64 ha and received a net profit of ₹15,000 after storing 2000 kg pods for domestic use and seed purpose in the next year.

He sold wheat fodder of ₹30,000 and made extra income. Balaram also planted 300 saplings of different trees (teak to guavas) as an agro-forestry interventions on field bunds.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Watershed activities help young farmer to achieve his dreams

Vegetables in Komal's field has provided extra income and required nutrition for the family

Komal, a young progressive farmer from Parasai has 4 ha land and has been instrumental in convincing other fellow farmers/youths about the watershed activities. Earlier, before the watershed interventions, he used to do farming in only 2.4 ha land.

During *Kharif* he used to grow groundnut crop and harvested nearly 1000 kg pod; Whereas in rabi, he was harvesting nearly 4000-5000 kg wheat from 2.4 ha land. He had 2 buffaloes with average milk yield of 6-7 liters per animal. He was spending nearly ₹2000 per month to meet fodder requirement of the animals. His annual household income was nearly ₹1,50,000-2,00,000 before year 2012.

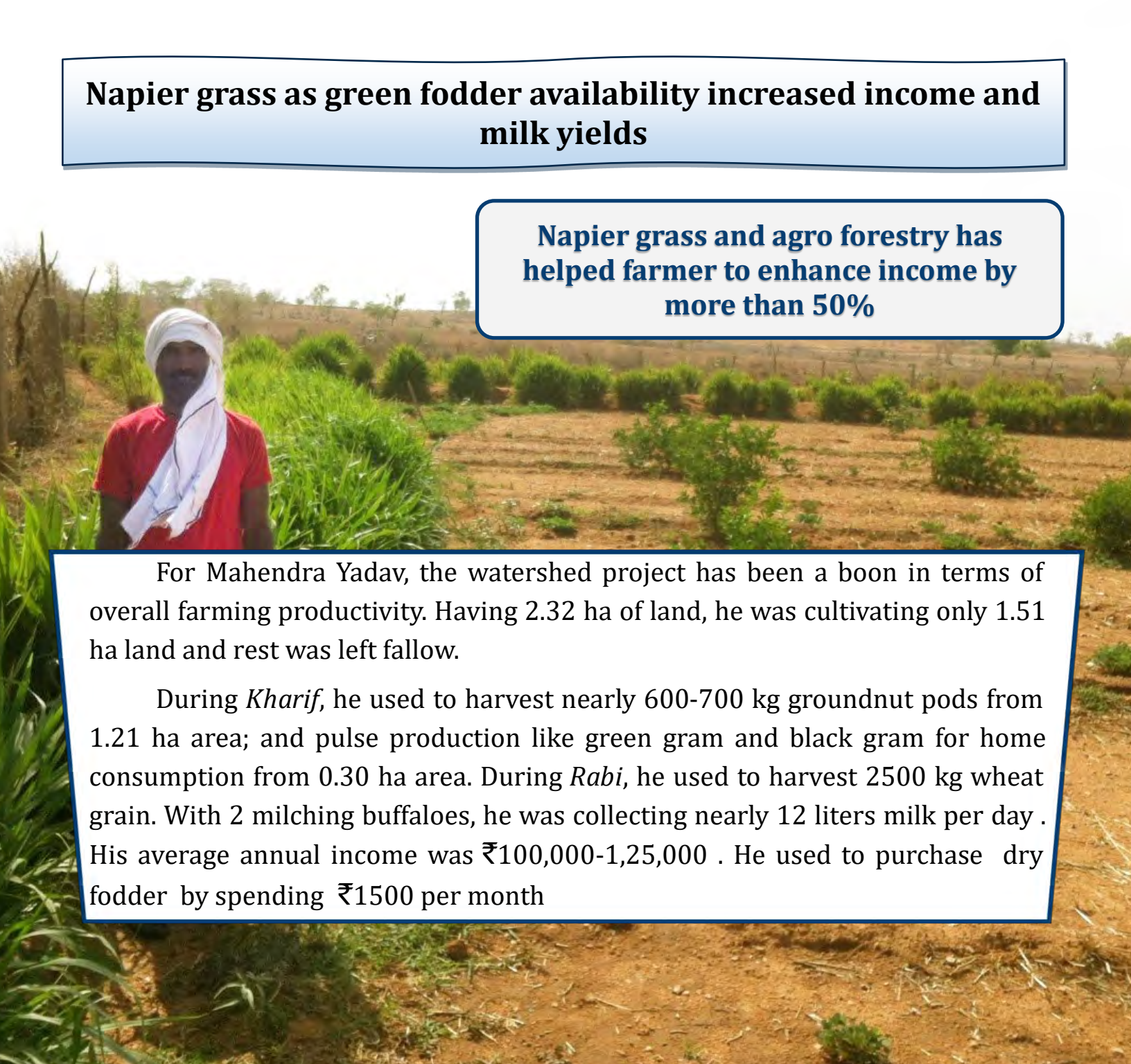
After the watershed project, the water level in the wells increased by 3-4 m and Komal is now cultivating all 4 ha land both in *Kharif* and *Rabi* season. He started growing groundnut, black gram and mung beans during *Kharif* .

Komal harvested nearly 8000 kg groundnut pods and 10,000 kg wheat from 3.23 ha of land. In rest of the area, he is growing winter vegetables and fodder crops. He now has 6 milking buffaloes with increased water and fodder availability. His annual net income is about ₹3,50,000-400,000, clearly indicates net gain of minimum ₹200,000/year compared to before watershed scenario.

Increased water availability helped Komal to utilize fully his field during *Rabi* season

Napier grass as green fodder availability increased income and milk yields

Napier grass and agro forestry has helped farmer to enhance income by more than 50%



For Mahendra Yadav, the watershed project has been a boon in terms of overall farming productivity. Having 2.32 ha of land, he was cultivating only 1.51 ha land and rest was left fallow.

During *Kharif*, he used to harvest nearly 600-700 kg groundnut pods from 1.21 ha area; and pulse production like green gram and black gram for home consumption from 0.30 ha area. During *Rabi*, he used to harvest 2500 kg wheat grain. With 2 milching buffaloes, he was collecting nearly 12 liters milk per day . His average annual income was ₹100,000-1,25,000 . He used to purchase dry fodder by spending ₹1500 per month

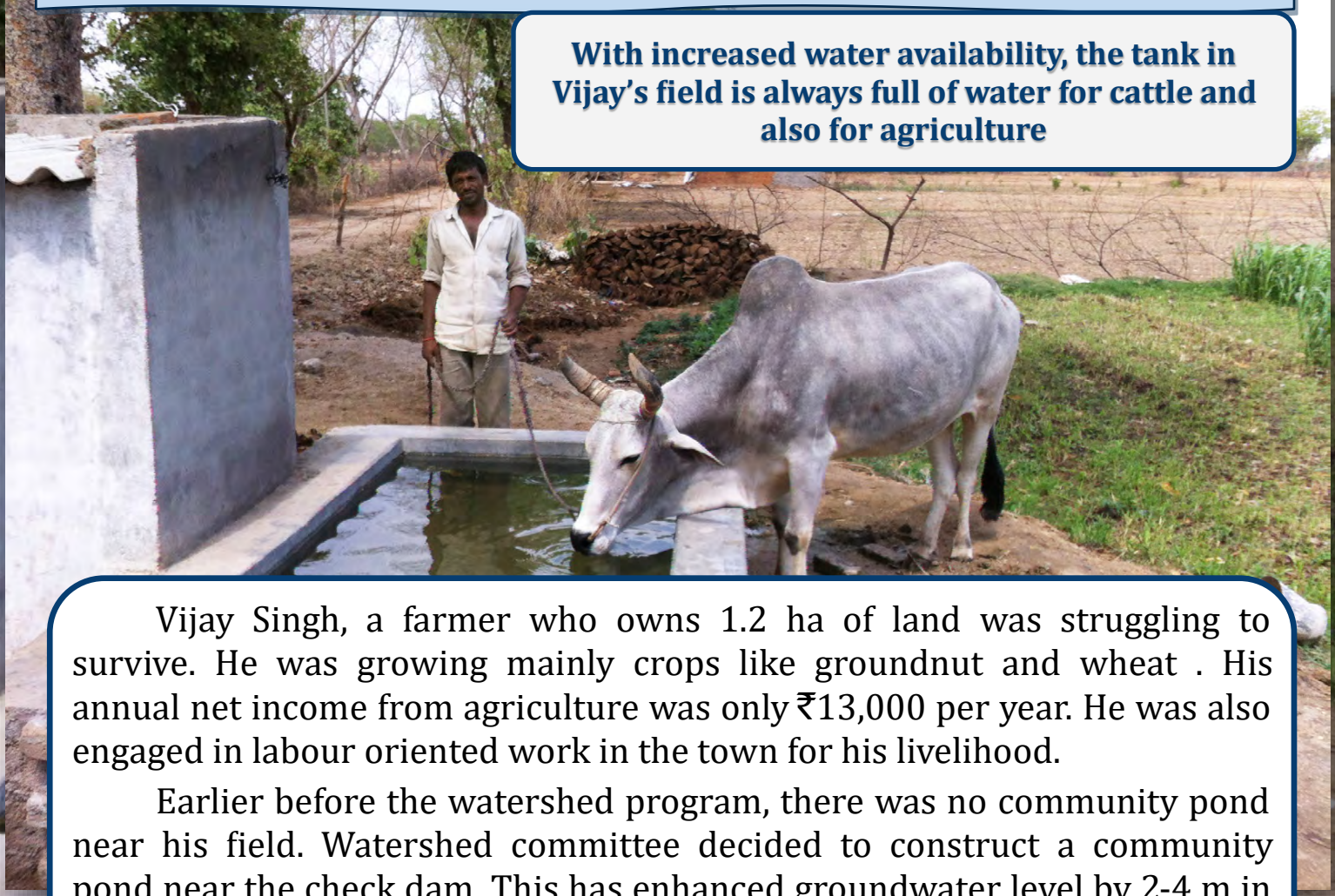
Under the watershed project, check dams were constructed. In this series, a pond was dug out close to his field. This has enhanced groundwater availability even during drought years. He also planted Napier grass around the field bunds as advised by CAFRI/ICRISAT scientists. Under the project activities, guava, pomegranate, teak and Napier grass was distributed to help the farmer with future opportunities to earn more income.

After the watershed project, he could cultivate groundnut in 2.32 ha and received a total production of 1700 kg; and harvest 5500 kg of wheat during Rabi. Napier grass has grown wells and therefore his expenses towards fodder minimized. Average milk yield per buffalo also increased by 2 liters.

The farmer (Mahendra Yadav) are now able to earns nearly ₹2,00,000-3,00,000 per year, has made significant difference in his livelihood.

Napier grass has proved a good source of feed for livestock and has increased milk yields by 2 liters per animal

From migrant laborer to a successful farmer, Vijay Singh has seen it all



With increased water availability, the tank in Vijay's field is always full of water for cattle and also for agriculture

Vijay Singh, a farmer who owns 1.2 ha of land was struggling to survive. He was growing mainly crops like groundnut and wheat . His annual net income from agriculture was only ₹13,000 per year. He was also engaged in labour oriented work in the town for his livelihood.

Earlier before the watershed program, there was no community pond near his field. Watershed committee decided to construct a community pond near the check dam. This has enhanced groundwater level by 2-4 m in his well.

Young and healthy teak along with Napier grass in Vijay's field

Witnessing the above, he dug a well at an expense of ₹40,000 and now even during severe drought in year 2015 he could pump water for one hour every day. During good rainfall year (year 2013), he could be able to pump water continuously for 24 hours.

He now is a busy farmer and does not go for labour works in the town. He now has two milching cows, which provide nearly 180 liters milk per month. By cultivating groundnut, he harvested nearly 1100-1200 kg pods during *Kharif* and made income of ₹30,000 from his field. He has also started growing vegetables such as okra and bitter gourd and generated income of ₹6,000 per season. By cultivating wheat in Rabi, he received net gain of nearly ₹15,000.

From a meager ₹13,000 per year, Vijay now earns more than ₹1,10,000 per year and also is able to sustain the family from his own production (wheat, groundnut, vegetables and milk). He started growing fodder crop-M P Cheri and saved more than ₹1000 per month on fodder expenses.

As a part of the project, teak, pomegranate and guava saplings have been distributed and planted. Vijay also has hopes to enhance his income these agro forestry interventions over the years.

Water gushes out from Vijay's well and helped to cultivate fodder crop during extreme drought year

Live wells during extreme drought in Parasai-Sindh watershed

The Parasai-Sindh watershed encompassing an area of 1246 ha and covering three villages (Parasai, Chattpur and Bachauni)

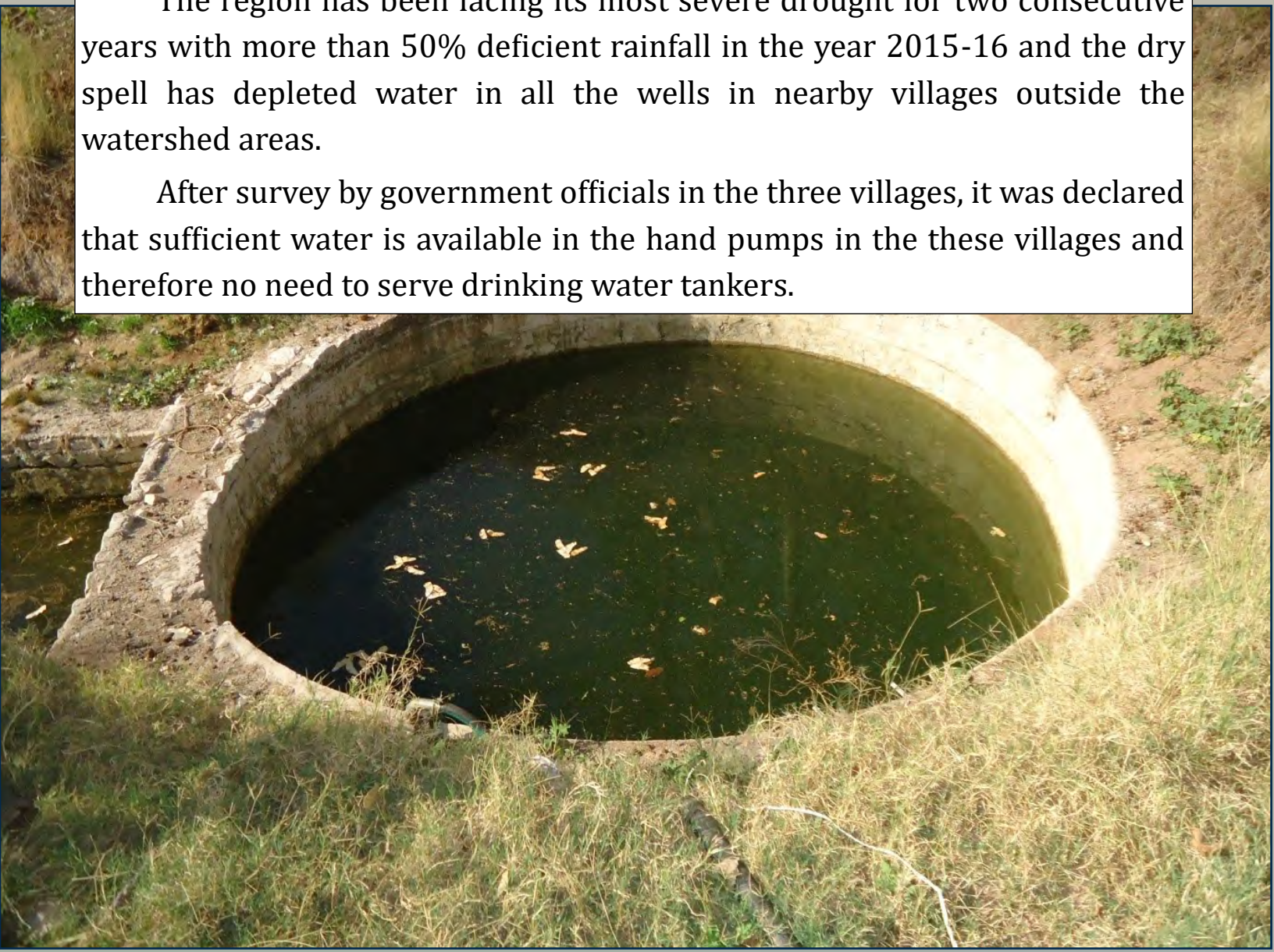
Water harvesting enhanced groundwater availability. No water-tankers required in these villages (Parasai, Chattpur and Bachauni) even in extreme drought situation of year 2015

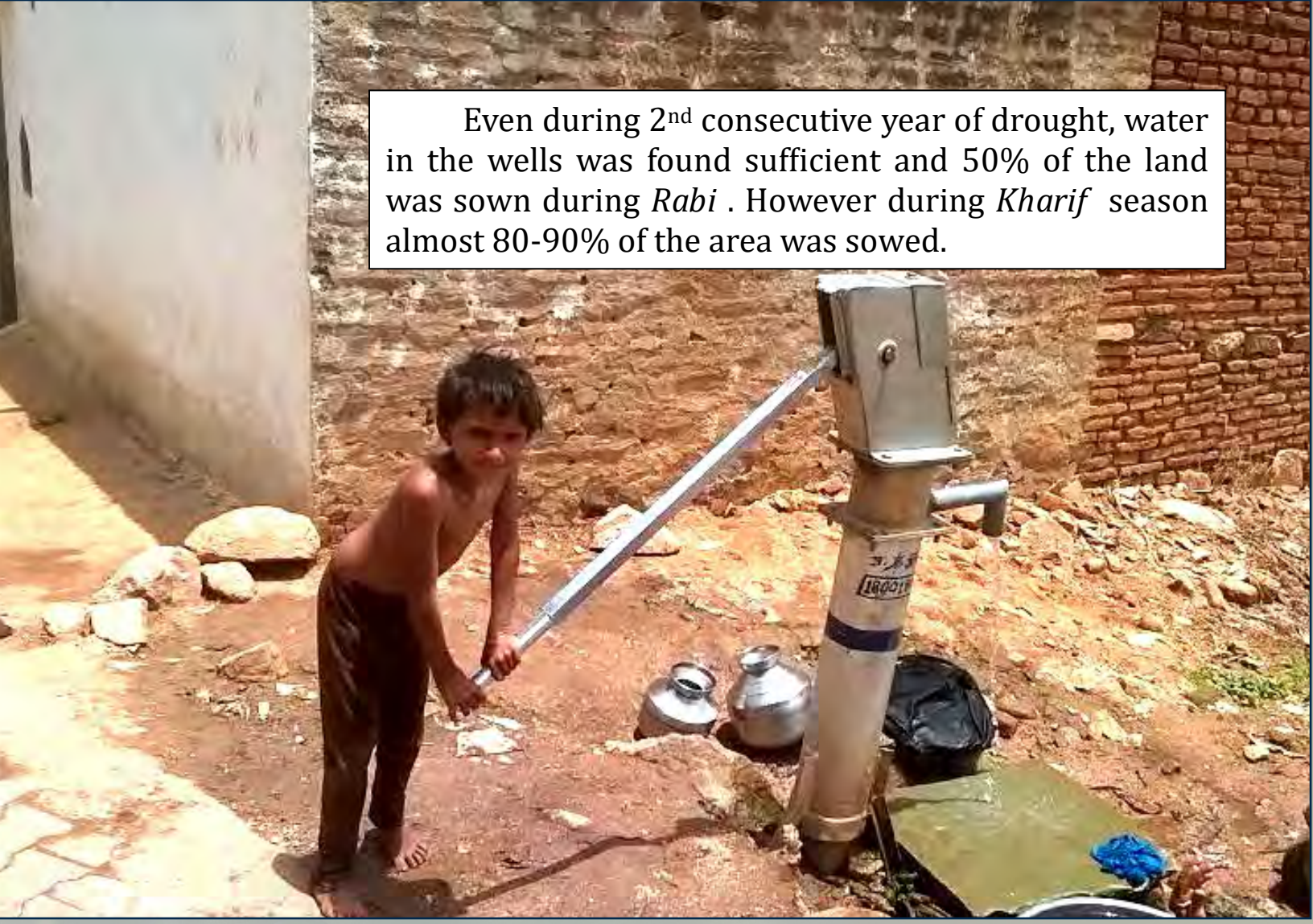
The watershed activities has increased water levels in the wells ranging from 2-4 m . This has also ensured that residents do not need to stand in long queues to collect water for domestic purpose in extreme drought situation of year 2015 as it had happened in nearby villages. Before watershed interventions, residents in these villages were also forced to stand in long queues and were largely dependent on outside tankers for their domestic use.

Watershed villages escaped water woes during severe drought from the past 2 years

The region has been facing its most severe drought for two consecutive years with more than 50% deficient rainfall in the year 2015-16 and the dry spell has depleted water in all the wells in nearby villages outside the watershed areas.

After survey by government officials in the three villages, it was declared that sufficient water is available in the hand pumps in the these villages and therefore no need to serve drinking water tankers.





Even during 2nd consecutive year of drought, water in the wells was found sufficient and 50% of the land was sown during *Rabi* . However during *Kharif* season almost 80-90% of the area was sowed.

One single good rainfall year in 2013-14 has supported a year of drought in 2014-2015 with 100% efficiency in terms of crop productivity and drinking water supply and the next consecutive year of drought (2014-2015) has also ensured drinking water needs for the three villages.

Nonexistent road now shown a lease of life due to watershed activities

The Parasai watershed has not only increased water levels in the wells ranging from 2-4 m but has also provided connectivity between villages. In Parasai village, as much as 200 metres of road was inaccessible/non motorable due to constant overuse by residents of the village.

Earlier before the watershed activities, residents of the village who had to travel to villages Kudain and Hatlab in nearby Madhya Pradesh had to walk for more than 2 hours due to the dis-connectively of road.

Residents of village in a meeting to help construct road in Parasai village

Despite repeated complaints to District Officials to repair the roads by the residents of 35-40 villages, no action was undertaken and residents continued to suffer. During watershed activities, it was decided that a community pond should be built and the excavated sand from the pond will be used to build a road. In order to build a road, nearly 800 m path was made.

Sand from the land was lifted to construct the stretch

After the road was repaired, residents could save two hours travel time to visit nearby villages. It has benefitted school going children, milk traders and farmers from all the three villages. It clearly shows that proper community engagement and collective action can resolve many problems without much investments.

Summary

The Bundelkhand region of central India is a hotspots of water scarcity, land degradation and poor socio-economic status. The Parasai-Sindh watershed, comprising three villages and covering nearly 1,250 ha, was selected for developing a benchmark site in Jhansi district to serve as a pilot for developing sustainable rural livelihoods thru efficient natural resources management .

In the year 2012, The International Crops Research Institute for the Semi Arid Tropics (ICRISAT) along with national partners ICAR-CAFRI (Central Agroforestry Research Institute), district administration, government of Uttar Pradesh and local community started implementing watershed interventions in these villages as a pilot watershed with financial support from Coca Cola India Foundation .

As a part of the project, rejuvenation and repair of the old "Haveli" in Parasai village has ensured 75,000 m^3 storage capacity. Also, the construction of 9 check dams, 3 nala plugs and 1 farm pond has further enhanced storage capacity of 40,000 m^3. The improved crop and water management practices resulted in increased crop yields by 50 to 100 % over farmers practice and increased cropping intensity by 30 to 50%; resulted into increased annual household income from 50,000 to 125,000 .

Also, more than 200 participatory crop demonstrations through the introduction of improved cultivars, agroforestry interventions through the distribution of fruit and seedlings of different tree species and income-generating activities such as vermicomposting, nursery plantation etc. has undertaken. This ensured the reduction in migration of residents during drought and increased overall productivity in the watershed villages.

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