Agricultural water management interventions for enhancing water resources availability, cropping intensity and various ecosystem services in Bundelkhand region of Central India

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Bundelkhand region of Central India is hot spot of water scarcity, land degradation, low cropping intensity, poor crop and livestock productivity and poor socio-economic status. Nearly 70% of the population of Bundelkhand is dependent on agriculture and allied sectors for its livelihood. A National Sample Survey report of 2017 shows that the per capita income in Bundelkhand is nearly ₹25,000, far below the national average (₹103,000) and those of Uttar Pradesh (₹43,800) and neighboring Madhya Pradesh (₹56,200) and Rajasthan (₹76,900). Given that strategies that focus on transforming agricultural and allied sectors are key to improving livelihoods of rural populations, the Government of India laid the pathway for doubling farmer's incomes by 2022.

ICRISAT along with ICAR-CAFRI has developed one of the pilot watershed (called Parasai-Sindh) of nearly 1250 ha in Babina block, Jhansi district in between 2012 and 2016. Total nine masonry structures having storage capacity between 5000 and 10000 cubic meter and a water harvesting tank of nearly 125,000 cubic meter storage capacity were developed. Intensive data on watershed hydrology, cropping system and agricultural productivity were measured since inception of project period. Study showed that construction of rainwater harvesting structures significantly altered landscape hydrology. Nearly 250 mm of surface runoff which earlier were leaving from the watershed has reduced by 40% (i.e., 150 mm) and equivalent amount of freshwater is made available as in form of groundwater and groundwater table increased by 2-5 m. Increased groundwater availability facilitated for crop intensification (140-160 %) compared to 80-100 % under the non-intervention stage. This has resulted into increased household income (from 50,000 INR to 145,000 INR/HH/year) compared to non-intervention stage. Moreover,

increased groundwater levels also helped to enhanced base flow availability as more than 80-100 days water is being received at stream networks after the receding of monsoon.

With such realization, ICRISAT along with national partners (ICAR-CAFRI, Jhansi; ICAR-IGFRI, BUAT, NGOs, etc.) are in process of developing seven pilot sites, each of 5000 ha in all seven districts of UP Bundelkhand region as a scaling up model with support of Government of Uttar Pradesh. No of water harvesting structures such as *Havali* renovation (traditional water harvesting tanks) and other structures is being constructed as per water balance approach. Water harvesting capacity of nearly 0.5 Million cubic meter has already been developed at pilot site. Agro-forestry interventions (e.g., teak plantation on field bunds, ber budding, high density plantation, etc.) have also been targeted at larger scale along with water harvesting interventions to strengthen the regulatory and supporting ecosystem services. Moreover focus is also given for productivity enhancement interventions, fodder development, animal breed improvement, mechanization and other livelihood activity through undertaking large scale frontline demonstrations, training, capacity building and organizing exposure visits. We investigate that these pilot sites will not only serve as site of learning but also the potential research/study sites for understanding complex biophysical, hydrological and socio-economic issues and would formulate drought proofing strategy of the Bundelkhand region.

Key words: water balance, drought proofing, Bundelkhand region, water harvesting, natural resource management

1. Introduction

Bundelkhand region of Central India is a hot spot of water scarcity, land degradation, poverty and poor socioeconomic status. Due to poor groundwater potential and high temperature, agricultural productivity in this region is very poor (0.5–1.5 t/ha). Most of the areas are single cropped and completely under rainfed conditions (Singh *et al*, 2014). Rainfall is highly erratic, both in terms of total amount and its distribution over time. Long-term weather data monitored at Jhansi station (nearby site) show that annual average rainfall in study region is 877 mm (standard deviation, σ = 251 mm) with about 85% during June to September. Long-term data analysis showed that annual average rainfall has decreased from 950 mm between 1944 and 1973 as compared to 847 mm between 1974 and 2004. This reduction was mainly due to decreased number of low (0–10 mm) and medium rainfall (30–50 mm) events. Similarly, total number of rainy days in a year also decreased. Dry spells longer than 5–7 days are very common and occur several

times (5–6 times) per season, whereas 10–15 days or longer dry spells also may occur during the monsoon period.

Soils in the region are reddish to brownish-red in colour (Alfisols and Entisols), coarse-gravelly and light-textured with poor water-holding capacity (80–100 mm/m). A large extent of the region is in degraded stage, and poor in organic matter and nutrient status. The geology of the targeted region is dominated by hard rocks of Archaen granite and gneiss and largely composed of crystalline igneous and metamorphic rocks (Tyagi, 1997), and aquifers are either unconfined or perched, having poor storage capacity (porosity of 0.01–0.05%). Shallow dug wells of 5 to 15 m depth are the only primary source of water for domestic and agricultural use in this region (Singh et al., 2014).

Frequent droughts are common in Bundelkhand. More than 80% of open wells get dried out soon after monsoon period due to deficit rainfall and poor groundwater recharge. In the absence of drinking water availability and poor livelihood opportunity, a large number of the rural community usually migrate to nearby cities. Lack of availability of water has affected the agricultural sector. The urban and rural communities largely depend on outside water source and private suppliers such as tankers for domestic use especially in summer. Cattle were abandoned due to shortage of water and less fodder availability. In such conditions, watershed development programme is considered to enhance groundwater recharge and reduce water scarcity with effective interventions.

2. Parasai-Sindh watershed, Babina block, Jhansi district

International Crops Research Institute for the Semi Arid Tropics, Hyderabad (CRISAT) consortium, with Central Agroforestry Research Institute, Jhansi (ICAR–CAFRI), selected one of the mesoscale watersheds, Parasai Sindh in Jhansi district to demonstrate the impact of watershed development interventions on groundwater recharge and strengthening ecosystem services. This watershed is located in Babina block of Jhansi district, Uttar Pradesh and covers 1250 ha of geographical area. It comprises three villages, namely Parasai, Chhatpur and Bachauni located between 25°23’56” to 25°27’9” N and 78°19’45” to 78°22’42” E. The watershed development programme in selected villages was started in 2011 with the objectives: (i) to enhance groundwater recharge and reduce water stress situation; (ii) to enhance agricultural productivity and water use efficiency; and (iii) to improve livelihoods of rural community.

3. NRM Interventions Implemented in Parasai-Sindh Watershed

3.1 Rainwater harvesting

Construction of low-cost water-harvesting structures is one of the important interventions considered for groundwater recharge. These structures harvest a substantial amount of surface runoff, allow it to percolate into aquifer and facilitate groundwater recharge. A number of locations for harvesting surface runoff were identified (one *Haveli* tank renovation, seven check dams, two farm ponds, one village pond and nearly 25,000 running meter field bunding) in consulting with watershed committee and village members and nearly 125,000 m3 of storage capacity was developed (**Fig 1**).

Fig. 1: Water harvesting and agroforestry interventions undertaken at Parasai Sindh watershed during project development

3.2 Productivity enhancement interventions and crop diversification activities

Yield gap analysis undertaken by ICRISAT revealed that large yield gap exists in the major rainfed crops grown in the semi-arid tropics. Further, there is a potential of increasing the productivity by two- to threefold using available technologies in farmers' fields (Wani et al., 2012). Soils in rainfed areas have low moisture content and are deficient in essential nutrients. Soil analysis showed 65–80 % of the farmers' fields were deficient in sulfur (S), zinc (Zn) and boron (B). In this context, farmers' participatory trials were

conducted in different years to demonstrate the impact of micronutrients (Zn and B) on groundnut yield. Application of B and Zn increased groundnut yield by 15–20% (average yield 1825 kg/ha) over control plots (average yield 1510 kg/ha) in 2011. During rabi, improved varieties of chickpea, lentil, wheat and mustard were introduced in farmers' participatory trials. Crop yields of improved crop varieties increased by 18 to 33% over local crop varieties. In addition, large scale agro-forestry works (teak/fodder grasses on field bunds, high density orchard, etc., refer **Fig.1**,) was also undertaken in project villages.

4. Results

4.1 Impact of watershed intervention on water resources availability and income

A number of water harvesting interventions and productivity enhancement activities, implemented at Parasai-Sindh watershed have made a significant impact on water resources availability, and income and livelihood of the farmers. Water, which was one of the limiting factors and a scarce commodity, enhanced significantly. Both surface and groundwater were found in surplus amount even at the end of the summer period. Hydrological monitoring showed that minimum 250,000 m3 of water was harvested in storage structures, which enhanced groundwater level by 2 to 5 m, with an average of 2.5 m compared to baseline status (before interventions). The NRM interventions have significantly changed the cropping pattern both in kharif and rabi seasons (**Fig.2**).

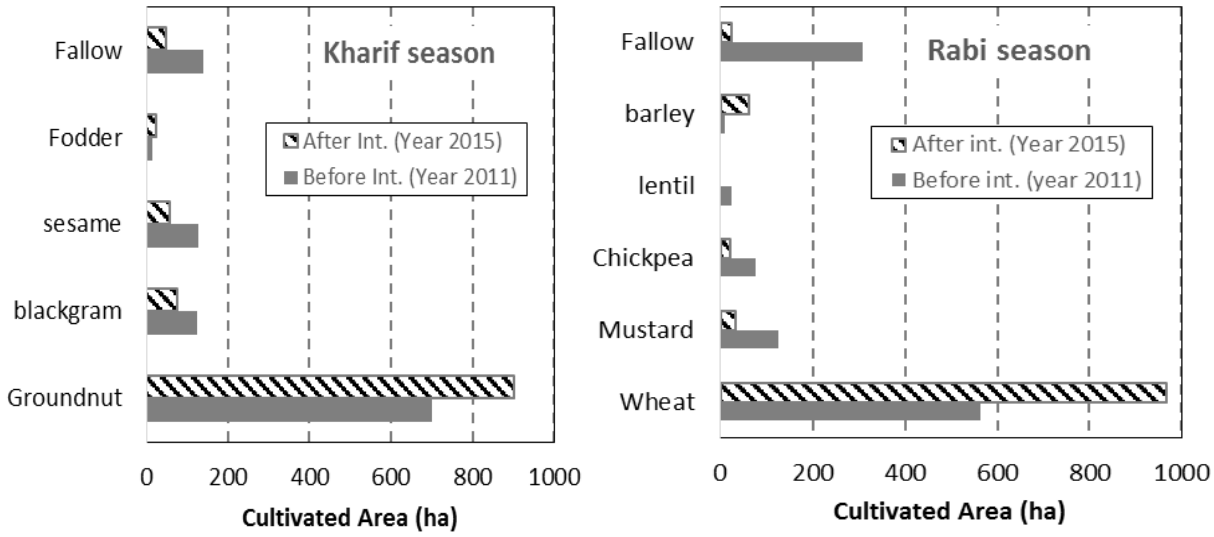

Fig. 2: Change in cropped area cultivated before and after the watershed interventions

With increased water availability, the cost of cultivation especially for wheat and barley has reduced. Before project interventions, farmers used to engage hired or family labour for more number of days for

irrigation work due to poor availability of groundwater as water in open wells used to deplete completely within 2–3 hours of pumping. Increased water availability (2–5 m increased water table in open wells) after the project interventions has facilitated farmers to complete irrigation in few days as they can pump water for 8–10 hours per day and therefore enhance labour use efficiency. This has reduced the cost of production especially for barley and wheat by reducing labour engagement. In addition, by introducing improved cultivars and management practices, wheat yield increased from 1.7 t/ha to 2.7 t/ha (**Fig. 3**). This all together made a compounding effect in enhancing net profit from agricultural production significantly. Yield and household data collected from pilot villages clearly showed that agricultural sector alone contributed towards enhancing net income from ₹20.8 million/yr to ₹58.4 million/yr (**Table 1**).

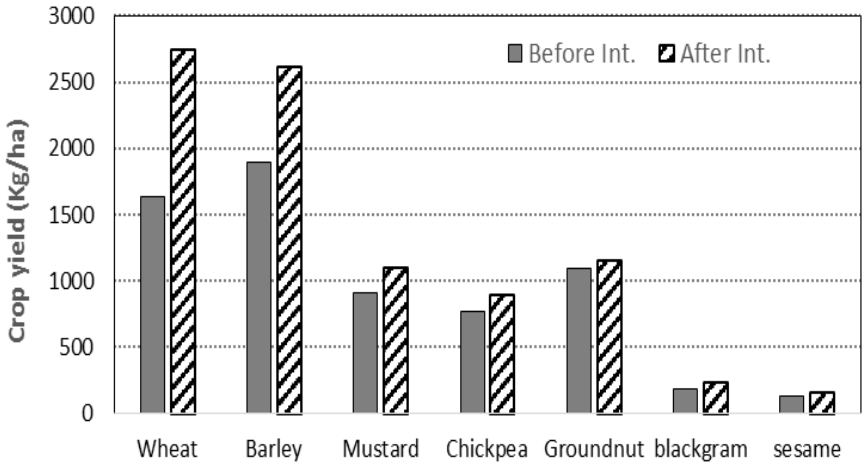

Fig. 3: Yield of different crops (kharif and rabi) measured before and after watershed interventions

The NRM interventions further improved fodder and livestock productivity. The number of buffaloes in project villages increased from 950 to 1300 with increased milk productivity of 2–3 l/day/animal. Livestock income increased from ₹10.2 million/yr to ₹21.2 million/yr, i.e. additional gain of ₹11 million/yr. Altogether, average household income in Parasai-Sindh watershed increased from ₹51,000 to ₹143,000 per household per year, clearly indicating that there exists a huge scope for enhancing farmers' income by more than double through implementation of various NRM interventions in the Bundelkhand region. In addition to agriculture and livestock sectors, project interventions also helped in enhancing other ecosystem services such as increased greenery, tree biomass and productivity and reduced soil erosion and carbon sequestration. Moreover, drudgery and migration levels have significantly reduced in pilot villages with increased domestic and agricultural water availability and livelihood opportunities.

Table 1: Impact on average household income before and after project interventions

Description	**Before**	**After**	**Diff**
Kharif area under cultivation (ha)	968	1057	89
Net income generated - *kharif* (Rs in million)	13.8	20.3	0.65
Rabi area under cultivation (ha)	797	1083	286
Net income generated r*abi* (Rs in million)	**-0.26**	**185**	**211**
Total net income from Ag (Rs in million)	11.2	38.8	27.6
Buffalo population	950	1300	350
Avg. milk yield (L/day/animal)	6	8.5	2.5
Annual income from livestock (Rs in million)	**10.2**	**21.2**	**11**
Total net income (Rs in million /year)	21.4	60	38.6
Number of households	417	417	-
Average household income (Rs ,000/year)	**51**	**143**	**92**

4.2 Scaling up of AWM interventions

Realizing these benefits of integrated watershed management, Government of UP has assigned the scaling up project to ICRISAT to replicate similar interventions in all the seven Bundelkhand districts (sites of learning) as part of doubling farmers' income initiative.

In May 2017, with the help of district administration (DM, CDO, JDA, DDA), the pilot sites covering about 5000 ha area (hydrological boundary) in all the districts were identified. Two to three villages were selected for developing the pilot site in each district (**Table 2**). Between May 2017 and June 2018, ICRISAT worked towards building rapport with the community with help of local NGOs. In this process, as an entry point activity about 200 soil samples per pilot site were collected, analysed and results were shared with farmers. Moreover, 50-100 farmers' participatory field demonstrations in each pilot sites were undertaken. To disseminate the results of crop demonstrations, field days were organized in all the districts. After receiving the project approval during June 2018, ICRISAT initiated forming the consortium of national institutes such as ICAR-Central Agroforestry Research Institute (CAFRI), Jhansi; ICAR-Indian Grassland and Fodder Research Institute (IGFRI), Jhansi; Banda University of Agriculture and Technology (BUAT), Banda; BAIF and local NGOs those are based in Bundelkhand region.

Table 2: Pilot villages identified in seven districts of Bundelkhand and the prevalent major cropping systems in kharif and rabi seasons

District	Block	Villages	Cropping pattern
Lalitpur	Talbehat	Pura-Khurdh, Birdha, Jhawar	Black gram, groundnut, mung bean, (kharif season- K); peas, wheat, mustard (rabi season-R)
Jhansi	Babina	Imiliya, Rajapur, Amarpur	Groundnut, mung bean, black gram, sesame (K); wheat, chickpea, mustard (R)
Jalaun	Mahiva	Noorpur, Naserpur, Hydalpur	Peas, Mentha, sesame, vegetables (K); wheat, chickpea (R)
Hamirpur	Sumerpur	Saukhar, Nazarpur, Karimati	Sesame, mung bean, black gram, sorghum, millet (K); mustard, wheat, chickpea (R)
Mahoba	Kabarai	Chandpura, Nathupura, Baniyatala	Peas, black gram, sesame, pigeonpea, mung bean (K); wheat, chickpea (R)
Banda	Thindwari	Benda, Amlikaur, Jauharpur	Pigeonpea, sorghum, sesame, mung bean (K); chickpea, lentil, peas, wheat (R)
Chitrakoot	Karwi	Rowli-Kalyanpur, Rasim	Mung bean, pigeonpea, sesame (K); wheat, peas, chickpea, lentil (R)

From June 2018 onwards, a large scale campaign on soil fertility management undertaken through wall writings and distribution of soil health cards along with undertaking farmers participatory field demonstrations. Soil test based results indicated that most of these pilot sites are deficient not only in organic carbon but also in available micro and secondary nutrients such as Zinc, Boron and Sulphur. To demonstrate the effect of balanced nutrient application on crop productivity, about 100-150 balanced nutrient management demonstrations were undertaken in each pilot site during Kharif and Rabi 2018-19. In addition, improved crop cultivars of sesame, green gram, black gram, wheat, chickpea, field pea, mustard were evaluated in more than 2000 farmers' fields.

Land form management practices such as laser guided land leveler was demonstrated in total 28 farmers' fields (covering nearly 60 acres) in Jhansi and Jalaun districts during Rabi 2018-19. This has benefited in terms of reducing labor and energy cost for irrigation application and enhancing water use efficiency. Moreover, use of zero-tillage multi crop planter was demonstrated nearly with 100 acres to reduce the seed quantity, cost of cultivation, encourage line sowing and more importantly better utilization of residue soil moisture available in surface soil layer.

In collaboration with ICAR-CAFRI, a large scale rainwater harvesting plan was developed and started implementing in pilot sites since May 2019 onwards. Total 20 rainwater harvesting structures which includes check dam, *Haveli* tanks, village tanks are constructed/renovated. Moreover, farm ponds, drainage channels were constructed at few locations and field bunding or trench cum bunding were made in 580 acres to enhance green water availability and controls soil erosion. These in-situ and ex-situ interventions created about 500,000 cubic meter storage capacity which would facilitate groundwater recharge in about 2500 acres.

In addition, agroforestry interventions were initiated with ICAR-CAFRI in all the seven pilot sites. Nearly 70,000 pits were excavated (up to 4 feet depth x 2 feet diameter) for planting teak, lemon, guava and other fruit saplings. A high quality tree saplings were procured from various forest department nurseries and also from ICAR-CAFRI. Two-year-old grafted saplings of different fruit trees were selected, distributed and being planted in all the seven pilot sites. Nearly 2000 local ber trees in 228 farmers' fields are being rejuvenated through budding.

For enhancing livestock productivity, sorted semen technology is being promoted in Chitrakoot and Mahoba pilot sites with the help of BAIF. A total of 142 cow/buffalos have been inseminated using sorted semen and out of them about 65% animals got pregnant. Pregnancy test kit was also used by farmers to detect the pregnancy status of their animal. Balanced nutrition feed trials were also undertaken in Banda and Chitrakoot to reduce mortality rate among small ruminants (goat) and also to enhance the growth of goat kids. Fodder interventions were initiated with help of ICAR-IGFRI since June 2019 onwards. Nearly 2000 kg of improved quality of folder seeds are made available in all pilot sites.

The consortium has undertaken number of capacity building programs (more than 10 per district) for different stakeholders such as farmers, masons, NGO staff on soil fertility management, mechanization, productivity enhancement, construction of water harvesting structures, agro-forestry, fodder development, balanced feeding, etc. Moreover, number of stakeholder workshops, review meeting, exposure visits were organized at ICAR-CAFRI, Parasai-Sindh watershed and pilot sites. Till date, more than 12,000 farmers/families have been directly benefited from this integrated system approach of DFI Bundelkhand initiative; however, there are large scale indirect benefits are also being observed.

5. Conclusion

Dryland area in the Bundelkhand region has huge untapped potential which can be harnessed through natural resource management. AWM interventions is identified as an adaption strategy for increasing agricultural production and income under the present and future climatic situation of dry lands and also Bundelkahnd region of central India. This paper showed the case study of Parasai-Sindh watershed of Jhansi district which recently transformed from substance farming stage to the progressive stage due to various AWM interventions. Similar approach is being applied in one of the scaling up project in seven pilot sites of respective seven districts. AWM interventions is targeted to be scaled up in on-going project to the large scale for achieving the system level outcome to enhance rural livelihood along with strengthening ecosystem services.

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