CHALLENGE PROGRAMME ON WATER AND FOOD – CPWF SMALL GRANTS PROGRAM

A Best Practice Evaluation Report of a Number of Water Related Agricultural Technologies

Humana People to People India

International Water Management Institute, New Delhi

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Credits of this report goes to

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For Humana People to People India

Bharat Dayal
Project Leader

Project Title - Selecting and Scaling Up Water –Efficient Farming and Groundwater Recharge Systems among 3,000 Small Scale Farmers in Rajasthan, India (SG 508)

Output 1: A Best Practice Evaluation Report of a Number of Water Related Agricultural Technologies

Executive Summary

The main idea of the project was to test methods for reducing the demand of water in agricultural crops and enhancing the groundwater recharge through individual and community owned structures by involving the agricultural households within the project area in a farmer led research. In the long run, it is expected that the project interventions will check the rate of ground water depletion and the families can have sustainable livelihoods from increased income and reduced water usage.

Different cropping models were designed for water efficient agricultural technologies. It was found that certain models had more benefits in terms of water saving while others had more economic benefits (when compared to the control plots). This report presents eight such models, which serve the purpose of water saving and lead to reduced pesticide use, increased yields and economic returns. The results from the various models are summarized below:

- Sowing Dhaincha prior to mustard in the model plots saved 57% water by increasing the organic matter content of the soil. In addition to this, the farmers have found out that the incidence of white rust in the model fields was reduced upto 30% and the quality of seed was found to be better.

- Water usage in wheat was reduced by the use of small check basins and it was observed that the total expenses for the irrigation component are reduced by 23% in the model plots.

- Sprinkler irrigation technology leads to additional water saving of 34% in the model plots when compared to the conventional sprinkler irrigation method.

- The Furrow Irrigated Raised Beds (FIRB) leads to a saving of 49% water and allow the farmer to sow twice the area in the same time and with the same amount of water (as used in the conventional method).

- Integrated crop management can be practiced in the cotton crop with the introduction of okra as a trap crop. This leads to 41% water saving and 58.2% saving on economy as compared to the conventional cotton crop.

- The Cotton + Moong combination lead to reduction in the usage of pesticides and water. There is 37.2% water saving and 94.68% saving on economy in this model.

- The Arhar + Moong combination model serves the purpose of crop diversification along with reduced pesticide and water use. There is 49 % water saving and 69% saving on economy in this model.

- The model gardens designed were also economically feasible and yielded quick return.

As far as the grain yield is concerned, the results were more or less similar as from the control fields in spite of the fact that reduced irrigation was given in the model fields. The model fields recorded an increase of 14%- 25% in the net profit.

The above results from the farmer led research proved that the depleting water tables could be controlled, at the same time livelihood can be sustained from increased income. Moreover, the objective of saving water for the future can be achieved as a result of the movement started by the farmers in the region and through further replications of the models.

Demarcations being done in the field of Satyaveer of village Riwali which will be used as a model garden.

Introduction

Humana People to People India has implemented the project in Behror block of Alwar District (Rajasthan, India) involving 3,000 households, to reduce unproductive uses of water and improve agricultural productivity.

The project commenced in January 2006 and concluded in June 2007. A number of different cropping practices designed for the whole year included both the *Kharif* (monsoon) and *Rabi* (winter) crops, grown generally in the area like cotton, *bajra* (pearl millet), mustard, wheat etc., so as to reduce water usage. This report contains analysis of results from the different models and the comparative analysis of the different improved models vis-à-vis the conventional systems. The analysis of each of the new models in the report helps to conclude as to what was worth adoption and up scaling and what could be further improved upon to suit the local conditions.

Background information of the operational area of the project site: Behror block (Alwar)

Geographical Position: The district Alwar is situated in Rajasthan bounded on the East, West and South by by Bharatpur, Jaipur and Dausa districts respectively.

Climate and Rain fall: The climate is moderate with hot dry summers and a bracing cold winter. The cold season starts from December and continues till February, while rains start from June and continue up to the first half of September. The temperature continuously rises in the season from March to June and goes down after mid November and further declines till the month of January. The meteorological laboratory setup in Alwar provides details about the climate in the entire district. The annual rainfall of the district is 657 mm while for Behror *tehsil* in which we have our operational area it is 666 mm.

Extent of Ground Water Exploitation: 218.44%

Position of Behror Block in terms of Availability of Ground Water: Over Exploited

Ground Water Quality: Since there is no perennial river in Behror block, the ground water is the only source to fulfill the water requirement of this area. The groundwater levels are falling and there is deterioration in the water quality. The water quality is adversely affected by the increased industrial effluent due to rapid industrialization of this area and is creating very serious water quality problems at many places of this block. Villages of this block are facing the problems of high contents of fluoride, nitrates and salinity in drinking water.

Land Resources and Production

Alwar district has an important place in Rajasthan in agriculture production. Total geographical area is 782,899 hectares, which is about 2.5% of the whole state. The kharif crops are grown on 41 % of the total area while rabi crops occupy 59% of the area. Area available for cultivation is 274,300 ha.

Soil type and cropping pattern: Behror block has mostly sandy-to-sandy loam soils with medium fertility. The cropping pattern is traditional in this area - in the kharif season bajra, jowar and gowar (cluster beans) are the major crops of cultivation and in rabi season wheat, gram and mustard crops are cultivated.

Irrigated and Wasteland: Ground water is the major source of irrigation in Behror block. Tube wells, dug wells and open wells are used for irrigation purpose. The irrigation facility is available in 11,000 ha (40%) of the total cultivable area. The wasteland which includes uneven land, Nallah, hillock etc is 2,625 ha (10%).

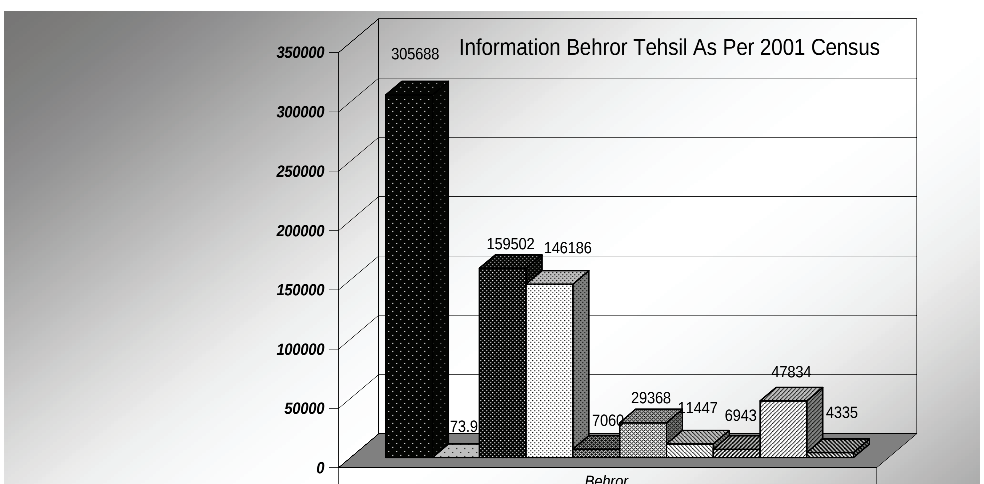
Infrastructure Facilities: About 98% of the villages of the block are electrified. The electricity consumption is to the extent of 9% for domestic purposes, 2.4% for commercial purpose, 54.8% for industrial purposes, 19.73% for agriculture and 14.07% for streetlights and other uses.

Transport and Communication: Behror is situated on Japiur- Delhi National Highway No. 8. . The region is not connected by rail therefore roadways is the only means of transportation available in the area The villages have postal and telegraph facilities through post offices, while the telecommunication facility is expanding very fast.

Agro-processing: There are no big agro-processing units for pulses, vegetables oils, fruit plants and vegetable produce. However, there are many cooperative societies working in this area like Gram Seva Sahkari Samiti, Dairy Cooperatives connected to the Cooperative Dairy Plant at Alwar.

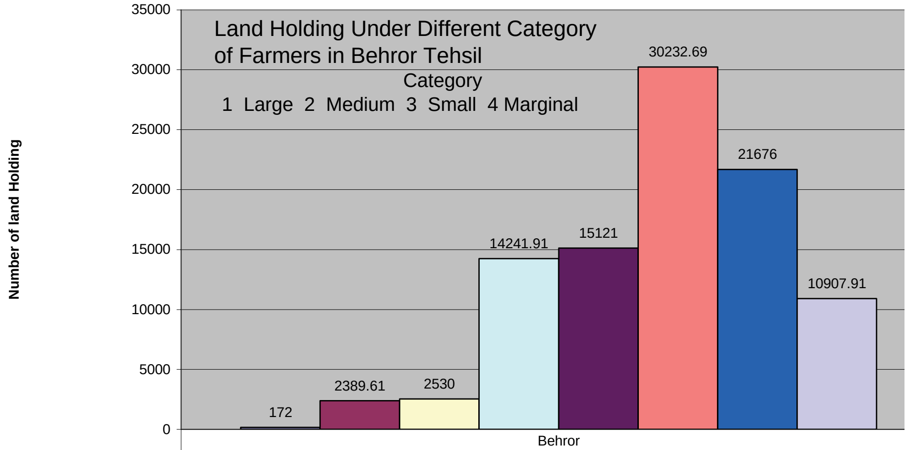
Storage Facilities: There are no storage facilities available in the *tehsil*. The nearest ones are in Khairtal and Alwar. These godowns, which are run by the state warehouse corporation and the Food Corporation of India, are mainly used for storage of food grains. There is no cold storage facility in the whole district.

Agricultural Research Activities: Agricultural Research Station and Krishi Vigyan Kendra (under Rajasthan Agricultural University) are working at Navgaon to cater to the needs of adaptable research, frontline demonstrations, training and education in agriculture and allied sectors in Alwar District.



	Behror
Population (as per 2001 census total)	305688
% of Literacy	73.9
Male No.	159502
Female	146186
Agri. Male	7060
Non. Agri.Male	29368
Agri. Female	11447
Non Agri Female	6943
SC	47834
ST	4335

Fig.1. Population details of Behror *tehsil* as per Census, 2001



	Behror
Large* No.Of Holding	172
Large* Area	2389.61
Medium* No.Of Holding	2530
Medium* Area	14241.91
Small* No.Of Holding	15121
Small* Area	30232.69
Marginal* No.Of Holding	21676
Marginal* Area	10907.91

Fig.2. Land holdings under different categories of farmers in Behror *tehsil*

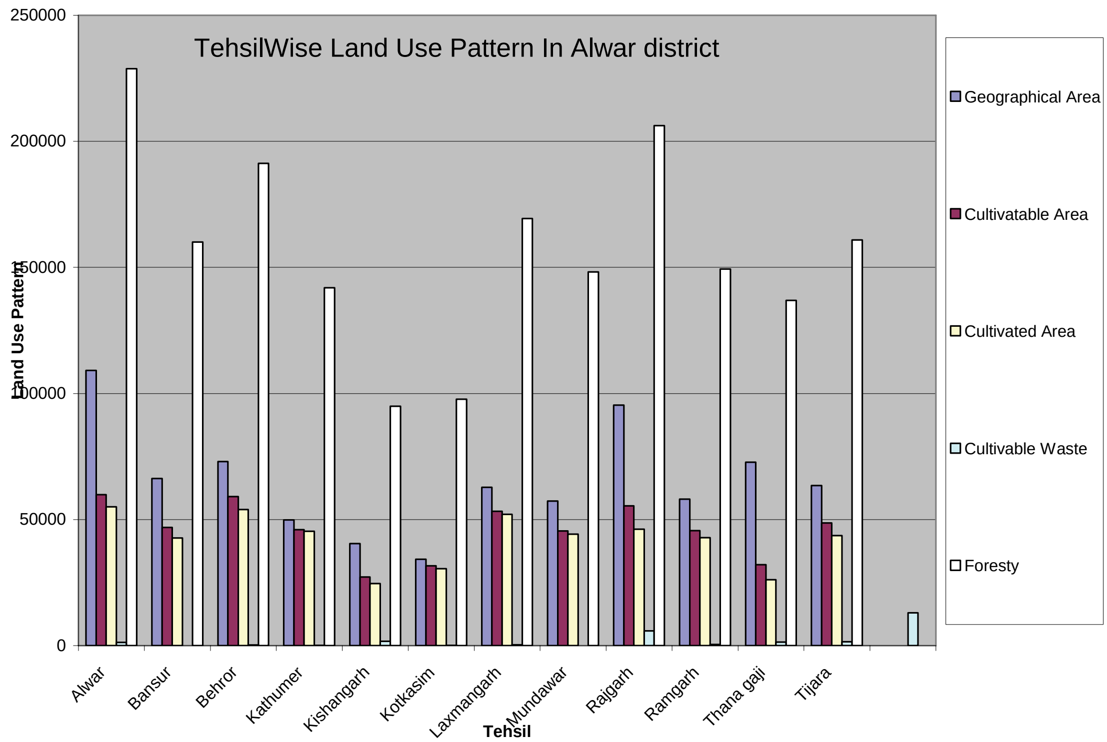


Fig. 3. *Tehsil*-wise land use pattern in different *tehsils* of Alwar district

Water Situation in Rajasthan

Rajasthan, the largest and the driest state in India, is in the grip of recurrent droughts. The main sustenance crops (i.e., kharif and rabi crops) are badly hampered due to inadequate irrigation water supply and unscientific management of canal water. Rajasthan covers 33 districts with an area of 21,500 million hectares out of which, Ajmer, Banswara, Barmer, Bikaner, Churu, Dungarpur, Jaisalmer, Jalore, Jhunjhunu, Jodhpur, Nagaur, Pali and Udaipur have been identified as drought prone (out of the total 99 drought prone districts in the country). Nineteen per cent of India's total area, comprising 12% of the population, is considered drought prone. Drought in Rajasthan is a recurrent and persistent phenomenon - 43 of the past 50 years can be described as "drought years". Despite huge expenditure being made on drought relief year after year, the vulnerability of communities to drought has vastly increased. This reflects the lack of effort made to address drought risk reduction. Increasing population levels and depleting water table levels continue to aggravate the intensity of the drought problem.

The vagaries of the monsoon could pose a bigger threat in terms of water availability for drinking and for livestock because the groundwater has already reached alarmingly low levels. The farmers have been forced to turn into wage earners and they have either started working as laborers or are hoping that the government would at least announce relief policies to provide them with an income to support their families. Rajasthan is yet to formulate a Drought Mitigation and Management Policy. The drought relief measures are based on old famine and scarcity codes. The total area covered by water management programmes in Rajasthan during the last 50 years is less than 5% of the total potential area, which calls for more work to be done to address this ever-increasing problem.

Methodology for the Research Project

Identification of a multidisciplinary team comprising a project leader, water technician, an agricultural technician, a program manager and social motivators and cooperating government departments like horticulture, agriculture, ground water board, etc was done for the development and finalization of the action plan for the operation area.

Training of the core staff for the execution of the project’s goals and objectives by the team comprising the project leader and requisite dignitaries was done during the initial period of the project’s intervention. Resource scientist from International Water Management Institute, New Delhi provided strategic help, guidance and training.

The main steps followed for the research were as follows:-

Orientation on the Concept of Water Saving: Communities were mobilized and oriented in the project objectives to enhance people’s participation, in the research led by farmers. Community animators were selected in each village to carryout the day-to-day project’ activities.

Identification of the Villages: Villages were selected for the research where farmers were found to be innovative and willing to participate in the farmer led research.


A progressive farmer participating in the project showing his diary to other farmers, where he is recording data as a part of farmer led resear

Collection, Analysis and Presentation of Data: This was done by comparing the baseline data with what was planned to be attained at the end of the project period so that the factors, constraints etc could be discussed and solutions found out in order to attain the goals.

Broad Propaganda about the Project in the Community: Stakeholder meetings and village meetings were conducted to develop participatory approach in project implementation and to seek community support. The plan of action and the role of the villagers in carrying out the farmer led research were discussed in the meeting. Meetings were also organized at the project office with the community leaders and other stakeholders to seek their views on different aspects of the project implementation and consensus was reached on the modus operandi of the project in each village.

Selection of Innovative Farmers for the Project: The farmers were meticulously selected from amongst those who were interested in the long term impact, serious in the project implementation and who came forward with a positive attitude for reducing water usage in their houses and in their fields.

Implementation of the Models: A farmer-to-farmer approach was adopted to see how it was possible for all the selected farmers to implement the models with respect to the available inputs (both physical and technical), at the sane time acknowledging the limitations. Monitoring tools were developed to assess the progress of the models with time.

Field days: Field days of farmers were organized to demonstrate the results from the farmers' models. 'Seeing is Believing' and 'Learning by Doing' was the logic behind these field days. This tool was planned to be effective tool in out scaling the project's models far and wide.

Exposure visits: The visits to research stations and also to other organizations was done for increasing the knowledge base of the farmers and also to see different techniques of water saving which could be adopted on their fields.

Different Cropping Model Designs for Water Efficient Agricultural Technologies

Even in water scarce states like Rajasthan and the most-overexploited blocks/ *tehsil* like Behror, the farmers continue to grow water intensive crops with water-inefficient irrigation practices. There can be several reasons for such wasteful practices, which include socio-economic reasons, little exposure to modern knowledge, energy policies in the state and continuation of the old traditions (when water availability was not a serious problem). The objective of this project was to alleviate the problem both through supply augmentation and demand management practices. This report presents the information related to demand management under which a number of innovative and water-efficient cropping models were identified, tested and demonstrated under the farmer led research mode of the project.

Detailed information on each of such innovative cropping model is given in the following sections.

Model 1. *Dhaincha (*Sesbania, Green manure) - Mustard

Background of the research

Low organic matter in the area (less than 0.2%, which is much below the normal requirement of 0.5 %) was found to be one of the critical factors for low fertility and water productivity. This called for a need to improve the organic matter content of the soil. Moreover, the water holding capacity of the soil increases with increased organic matter. This prompted the project to use the fallow land prior to sowing of mustard for the new intervention. Then we designed the model to see the increase in water status as a result of additional organic matter. Meetings were conducted with the farmers about the model. Testing for water holding capacities for soil with varying organic matter content were recorded. Three types of samples were taken (100% field soil, 75%field soil + 25 % vermicompost, 66% field + 34 % vermicompost). It was found that in the third case, the moisture holding capacity was the maximum. This proved to the farmer that he could save water by increasing the organic matter content of the soil. Farmers who practiced mustard cultivation were approached and oriented about the need to improve organic content of soil by growing green manure, which is locally called *dhaincha* (*Sesbania grandiflora*). Those who responded by earmarking a portion of their land for the research were identified. Model and control plots for all such farmers were demarcated. Models were the fields, which were to be sown with Dhaincha prior to mustard whilst control plots were left fallow as in the conventional method. Twenty-seven progressive farmers from the operational area signed up for this intervention.

Methodology

After the first rainfall of the season the fields were sown with *dhaincha* @ 60 kg seeds/hectare. They were left to grow unto 40 days after which they were ploughed with soil turning plough and left until sowing of mustard. Before sowing of mustard, moisture holding capacities (WHC) of the soil for the model field and control plots were tested for 5 samples and it was found that in the models the WHC was about 27 % higher as compared to the control plots.

The following irrigation saving treatments was tested to harness the benefits of higher organic matter and improved WHC:

T1: Only one irrigation given at the time of 50 days after sowing of mustard
T2: Two irrigations given at the time of 40 and 80 days after sowing of mustard
T3: Three irrigations given at the time of 30, 60 and 90 days after sowing of mustard (normal conventional method followed).

Every treatment had 4 replications.

Observations and Results

Total water requirement and economics for the various treatments per hectare for the whole crop period is given under Table 1. Net returns with one irrigation were comparable to those with three irrigations (traditional practice) and additionally it saved about 57% of precious water. Application of two irrigations under enhanced organic matter conditions saved water by about 25% and improved net returns by about 22% as compared to traditional practice.

Table1. Economics and water savings under *Dhaincha*-Mustard cultivation under varying water regimes

Component	T1: One irrigation	T2: Two irrigations	T3: Three irrigations
Gross returns, INR	31648	37912	34032
Cost of production, INR	9735	11435	12360
Net returns, INR	21913	26477	21672
Water use, cubic meters	640.7	1116.7	1487.4
Water savings (%) as compared to T3 (control)	56.9	24.9	--

The best option for the farmer as far as water saving is concerned is T1 (Treatment with one irrigation), whilst for best net return, it is T2 (Treatment with two irrigations).

Recommendation

Keeping in mind that this area is in the dark zone for ground water availability and seeing the farmer's interest, we can decide that T1 is the best-suited treatment for the area as the farmer gets the same return as from the conventional method. Moreover, the organic matter increase in the soil due to addition of *dhaincha* will improve soil health.
In addition to the above results, the farmers have exclaimed that the incidence of white rust in the model fields were reduced upto 30%. Moreover, the quality of seed was found to be better.

Model 2. Conventional Check Basin Vs Small Check Basin in Wheat

Background of the research

In the conventional method (big check basin of irrigation), water distribution is not even for the entire field. More water is available in the initial portion of the field (which leads to water logging) and this leaches nutrients downwards, making them unavailable for plant use. On the contrary, water does reach in optimum quantities in the rear part of the field, thus resulting in irregular growth pattern. At crop maturity the area of excess water, which causes uprooting of plants have a higher chance of crop fall in the hot winds. These are some of the disadvantages of the conventional method, which were identified by the project during its initial survey and subsequent interviews with the target groups. It was then decided to design methods, which could ensure even growth. The design developed was called small check basin under which the farmer had to divide his land into small basins, the size of which depends on the topography and the size of the field. The logic behind this design was that small check basins fill up the field in less time compared to big basins and thereby save water.

Methodology

Selection of farmers and demarcation of model and control plots was done for comparison. Tools were developed for recording water usage in the field, which the farmer could easily fill in. The farmers were given notebooks to record the time and duration of irrigation in the models as well as the control plots.

Observations and results

The comparative analysis of small check basins vs. traditional large plots for irrigating wheat is given under Table 2. The irrigations were given at the planned days. It was found out that in the model fields, on an average, for the whole crop period, 132.9 hours of irrigation were given while 172 .10 hours were given in the control fields per hectare. All other factors were kept the same except the hours of irrigation. Irrigation expenses for the model were Rs.5316/- per hectare as compared to Rs. 6884/per hectare for the control. This implies that the farmer saves Rs.1568/ on every hectare of land which he irrigates through this method. Thus, we observe that total expenses for the irrigation component are reduced by 23% in the model firlds. It was observed that less time is taken to fill up the model fields compared to the control fields. Moreover the problem of wheat lodging (during the maturity stage in case of control) is checked as water does not stand for long time at one place.

The yield recorded was 3.762 t/hectare from the model, compared to 3.436 t/hectare in the control.

Returns from the grains (@ 8.80/kg) were Rs.33105/- per hectare compared to Rs.29206/-per hectare in control. Only a marginal increase of Rs.3899/- in the returns from the grains in the model was observed which implies that there is 13.34% increase in returns from the grains.
With other factors remaining similar, we see that the total difference between the model and the control fields on net profit is Rs.5467/- per hectare

Conclusions and recommendations

We can deduce from the above results that if the farmer makes some effort for adopting the model he can save water to an extent of 730 cum/hectare. The dependency on erratic electricity supply, has prompted the farmers to adopt this method. Moreover, there are good results from the research and the farmers have started to take interest in the economics of the whole method and are inquisitive to adopt it in the next rabi season. Due to continuous depletion in water table in the area and the good adoption behavior exhibited by the farmer with special interest shown towards acceptance of this innovative method, it is recommended for the area.

Table 2. Comparative analysis of small check basins vs. traditional large plots for irrigating wheat

Components	Model Field	Control Field
Total No. of irrigation	6	6
Total irrigation hours required to mature crop	132.9	172.1
Avg. production of grains t/ha	3.762	3.436
Total expenses on irrigation @Rs 40/hrs	5316	6884
Return from the grains @ Rs.8.80/ kg, INR	33105	29206
Returns after deduction of irrigation exp., INR	27789	22322
Total water required to mature the crop, in cum	2475	3205
Water savings, %	22.78	---

Ramjilal of gunti made FIRB for locky ,tori, khira and made check basin for bhindi and guar which we measured as control plot for calculation of water usage

Model 3. Sprinkler Vs. Sprinkler(Wheat)

Background of the research

In this area it has been seen that the farmer uses 6 -7 hours of irrigation in wheat at the same site at one time. When the project survey was done and the technician inspected the fields and observed that the water used was much more than needed for the crop in terms of time. He was pretty sure that the root zone of the wheat crop can be saturated in 3 hours which he verified in the field by checking the moisture status after running the sprinkler in the farmers' field. The farmer was also satisfied following which more farmers signed up to test the research. Conventionally in the sprinkler system of irrigation, it is assumed that there is 30% water saving. The findings of the technician were put to test to a number of farmers' fields where sprinkler irrigation was not used.

Methodology

Farmers were selected, who were convinced and were willing to do such innovation. The fields were demarcated and water usage reading was taken after designing the model and number of irrigation were predetermined by the project. The number of irrigations in the models was 7 compared to 5-6 in the control fields, to ensure that the models are always having the requisite moisture for proper plant growth. Sprinkler sets were provided to some very progressive farmers by the project free of cost.

It is to be noted that in this method the farmer has to ensure that the moisture is available to the root zone i.e. unto 10cm of soil depth. The farmer verifies this by digging the soil to the root depth after irrigation. Irrigation is stopped when the required moisture level is attained. There were discussions between the project staff and the farmers individually as well as with groups execution process. Monitoring tools for assessing the progress of the farmers' fields were developed on which the project had complete control. There were 5 farmers who had adopted this method.

Observations and Results

The irrigations were given at the days planned as shown in the Table 3 below. The duration of irrigation in the models and the control fields was recorded for each irrigation. The interval of irrigations in model field was 15 days after the first and for all subsequent irrigations while 20 days interval was given in the control fields. The irrigation time plan for the model fields was followed. For the different models and for the different irrigations, the duration of each irrigation was decided by testing the moisture status at random from the fields and recorded.

The comparative analysis in terms of water savings and economy is given under Table 4. It was found out that in the model fields, 92 hours of irrigation were required for crop maturity while 138.3 hours were required in the control fields per hectare. In this research, all other factors were kept the same except the irrigation expenses, which were dependent on the hours of irrigation. Irrigation expenses as per the prevalent rates for the model were Rs.3680/- per hectare compared to Rs. 5540/- per hectare for the control. This implies that the farmer saves Rs.1860/- on every hectare of land irrigated through this method. Thus, we observe that total expenses for the irrigation component are halved in the model.

Yield recorded was 3.63 t/hectare (Rs.30855/-) from the model as compared to 3.482 t/hectare (Rs.29597/-) in the control.

Difference in Net Returns from grains is Rs. 1258/-. Thus, net returns after deduction of irrigation was Rs.3118/- per hectare as other factors remained same for model and control plots.

Conclusions and Recommendations

Additional water saving in the model was 34% when compared to the conventional sprinkler irrigation method.

The dependency of the farmers, in uncertain electricity supply has prompted the farmers to adopt this method as they can cover large areas through precision application of irrigation water, which also reduces leaching of nutrients in the sandy soils of the region. This also ensures less time in irrigation, more area can be irrigated and the chances of field being left un-irrigated are minimized. The farmer can manage with less water if he checks the soil moisture status while irrigating the field. This method is recommended to farmers even where the land is not leveled and where other methods like small check basin and FIRB Method cannot be implemented due to uneven topography or in sandy soil conditions.

Table 3. Irrigation Layout and Design of Model and Control Fields

Model Field		Control Field	
No of Irrigation	**Days on which irrigation given**	**No of Irrigation**	**Days between irrigation given**
I	20-25	I	20-25
II	35-40	II	40-50
III	50-55	III	65-70
IV	65-70	IV	85-90
V	80-85	V	100-110
VI	95-100	VI	115-120

Table 4. Comparison of precision and traditional application of water through sprinklers in wheat

Component	Model field	Control field
No of irrigation required	7	6
Total hours of irrigation required for crop maturity	92	138.3
Average production of grain in t /ha	3.63	3.482
Total expenditure on irrigation @Rs. 40/hr, INR	3680	5540
Return from the grain @ Rs.8.50/kg, INR	30855	29597
Return after deduction of irrigation expenditure, INR	27175	24057
Total water required to mature crop, in cum	1529	2300
Water saving, %	33.5	---

Model 4. Furrow Irrigated Raised Beds (FIRB) Method of Irrigating Wheat

Background of the research

There is a problem of crop lodging at the time of maturity in wheat crop as there are high velocities hot winds blowing during that period and when the farmer irrigates the field, there are chances of crop falling. This problem results in crop losses from 25-40% depending on variety, time of sowing and crop duration. The project tried to address this problem by making a design for irrigation where no standing water in the field is in direct contact with the plants. This will check the disadvantage of soil getting loose due to flooding and thereby falling off when hot winds are blowing.

Rajender of Kankarchajja has planted brinjal ,chillies and ladies finger through FIRB system for water saving

Methodology

In the furrow irrigated raised beds method, after every 3 rows of wheat, there is a furrow where water is given and the rows of wheat get irrigated through seepage. The field is made tabletop and in cases where the field is not leveled, the furrows are made across the slope to ensure uniform moisture level for different parts of the field resulting in uniform growth. In this model we expect:

1. A better quality of grain size to check the market losses due to poor quality of grains from the conventional method.
2. Intercultural operations enhanced by using the furrows.
3. Removed weeds used as mulch by spreading them in the furrows to check evaporation losses and retaining water for longer time in the field.

In this model, we have provision for 7 irrigations instead of 6 in the conventional during the whole crop cycle and the purpose is to ensure proper moisture (Table 5 shows the irrigation plan for wheat under model and control fields). The water fills up only in the furrows and it takes less time as compared to the conventional method (where the whole field is flooded).

Observations and results

Table 6 gives the comparison of FIRB vs. Check Basin method of irrigation. It was observed that in the model fields on an average for the whole crop period, 87 hours of irrigation were required for crop maturity (per hectare) while 172 hours were required in the control fields. In this research, all other factors were kept the same except the irrigation expenses, which depend on the hours of irrigation.

Irrigation expenses as per the prevalent rates for the model were Rs.3516/- per hectare compared to Rs. 6884/per hectare for the control. This implies that the farmer saves irrigation expenses of Rs.3368/ per hectare, which is approx. 50% through this method.

Out of every four lines, only 3 were sown with the crop and the fourth was replaced by the furrow, which resulted in the decreased yield. This means that in the model 75% area was sown however, the yield decreased by only 4.5% compared to same area sown on control fields. (Yield recorded was 3.282 t/hectare from the model as compared to 3.436 t/hectare in the control).

Returns from the grains in the model fields were Rs.28882/ per hectare compared to Rs.29206/- per hectare in control fields. This suggests only a marginal decrease (Rs.324/-) in the returns from the grains in the model. However, the saving on irrigation to the extent of Rs 3368/- brings the net profit in the model to Rs.3044/- per hectare.

Conclusions and Recommendations

This model is also an answer to the dependency of the farmers on erratic supply of electricity. Moreover, the farmer can sow twice the area in the same time and with the same water available as used in the conventional method. This method is recommended for farmers who wish to produce bold size of grains for seed production. Due to continuous depletion in water table in the area and the good adoption behavior exhibited by the farmer, this innovative method is recommended to be scaled up in the area.

Table 5. FIRB Model for Wheat – Irrigation Execution Plan

Model Field (FIRB)		Control Field (Check Basin)	
No. of Irrigation	Days on which irrigation given	No. of Irrigation	Days on which irrigation given
I	20-25	I	20-25
II	35-40	II	40-50
III	50-55	III	65-70
IV	65-70	IV	85-90
V	80-85	V	100-110
VI	95-100	VI	115-120
VII	110-115		

Table 6. Comparison of FIRB vs. Check Basin method of irrigation

Components	Model field	Control Field
Total no. of irrigation	7	6
Total irrigation hours required to mature crop	87.9	172.1
Avg. production of grains ,t/ha	3.282	3.436
Total expenses on irrigation, INR	3516	6884
Return from the grains, INR	28882	29206
Total water required to mature crop in cum	1638	3205
Returns after deduction of irrigation expenses, INR	25366	22322
Water savings, %	48.9	---

General comparative study of the various water saving interventions in wheat in the operational area

Wheat being the most expensive rabi crop of the region as far as water usage and wastage is concerned, a number of models were designed to test the results of water saving techniques. An analytical paper was made for each of the models to compare with conventional methods and conclusions were made. In the operational area, 34 .5% of the total cropped area is under wheat, 60% is under mustard and the rest is under other crops. Since mustard needs only two irrigations and wheat needs 5-6 irrigations, it is implied that the maximum water usage is in wheat and therefore, substantial amount of water can be saved in this crop by applying different innovative methods. In the designs developed and implemented by the project upto 50 % water saving has been established in the year. It has been observed that 23 % of water is saved by using small check basin, 52 % of water is saved by using sprinkler irrigation with reduced hours of irrigation (precision application) and 49 % of water is saved by using FIRB Method as compared to the normal conventional method of big check basin. These results are given in Table 7 below.

As far as the grain yield is concerned, the results were similar as from the conventional fields in spite of the fact that reduced irrigation was given in the models. The net profit was always higher in the models compared to the controls (ranging from 14%- 25% increase).

The doubts of farmers concerning whether the crop will fail or whether the land will remain empty (example told by farmer for FIRB) were removed after proper observations were recorded. The result is that more and more farmers have signed up for the different models for the next season. The above results from the farmer led research have proved that the need of the farmers and their interest can be taken care of. Moreover, the objective of saving water for the future can be achieved as a result of the movement started by the farmers in the region.

Table 7. Details on economics and water savings in wheat under different improved models of irrigation

Components	Conventional (large check basin Method)	Small check basin	Sprinkler conventional	Sprinkler model (precision application)	FIRB method
Total no. of irrigation	6	6	6	7	7
Total Irrigation hours required to mature crop, hour	172.1	132.9	138.3	92	87.96
Average production of grains, t/ha	3.436	3.762	3.482	3.63	3.282
Total expenses on irrigation, INR	6884	5316	5540	3680	3516
Returns from the grains, INR	29206	33105	29597	30855	28882
Returns after deduction of irrigation expenses, INR	22322	27789	24057	27175	25366
Total Water required for crop maturity	3205	2475	2300	1529	1638
Savings of water as compared to conventional method, cu m	0	730	905	1676	1567
Saving of water (%)		23	28	52	49

Model 5. Integrated crop management in cotton by introduction of ladies finger as a trap crop (Cotton + Okra)

Background of the research

Sucking pests attack leaves and the apical buds of cotton giving yellowish color and inverted cup shape to the leaves. This is mistaken by the farmer as a water stress condition leading to the application of unnecessary irrigations resulting in physiological disorders and affecting the growth of plants. Even the government functionaries in the region were not able to convince the farmers about this phenomenon and therefore, it was decided to design a model to address the problem of water wastage.

In the kharif season this is the only crop in which the farmer uses water in large quantities. Also, excessive chemicals are used as this region suffers from the problem of infestation of sucking pests. Therefore, it was decided by the project to design a simple model for the farmer to adopt easily, which could serve the purpose of saving water as well as reducing the excessive chemical usage.

Okra is used as a trap crop surrounding the cotton plots/fields. The farmers were convinced of additional returns from the trap crop, which could increase the family income. This model has the objective of reducing the investments in pesticides as a result of reduced attack of sucking pests and bollworms on the cotton crop.

The concept is that the pests attack from the boundary and when 5 lines of okra are planted surrounding the cotton crop, it prevents the movement of the pests towards the main field of cotton and this leads to the reduction in pesticide usage. The pesticides are sprayed on okra only due to which the attack of sucking pests as well as spotted bollworm on the cotton is intended to decrease. The crop also does not develop any symptoms similar to wilting and farmers do not apply additional irrigations.

The fortnightly observations showed that the growth of plants in control plot was poor compared to the model fields (plant height, plant canopy, no of fruiting bodies). Attack of sucking pest is more in the control plot compared to the model fields with the trap crop. Excess watering and fertilizers (in control plots) increases the dropping of fruiting bodies and ultimately reduces the yield of the crop.

Methodology

Fortnightly, cotton ecosystem analysis (CESA) was done to know the activities of insect pests and its effects on the growth of cotton crop. For this purpose, 3 replications were taken and 4 readings were taken fortnightly (observations were taken for crop age from 65 days to 125 days). In one replication, observations from 20 plants were recorded. For different plant characteristics, recordings were done both of the model and for the control and a comparative study was done for sucking pests, bollworms and plant height, plant canopy and fruiting bodies, and number of leaves.

Observations and results

Attack of all the sucking pests is more in the control fields as compared to model fields with trap crop of okra (Table 8).

Table 8. Average insect counts of sucking pests under control and model plots with a trap crop

Parameter	Model field with trap crop (Average count/ leaf)	Control plots (Average count/ leaf)
Jassids	0.96	1.48
Whitefly	1.41	3.56
Heliothis	0.16	0.33

Comparative economic and water efficiency analysis of model and control fields under cotton + okra is given in Table 9. On an average, it was found that only 3 irrigations were given in the model fields as compared to 5 irrigations in the control fields. Average water usage per hectare in the model was 1937 cu m compared to 3278 cu m in the control.

This is a result of non- appearance of symptoms in the models due to reduced attack of sucking pests, which were otherwise taken by farmers as water stress conditions.

Conclusions and Recommendations

This model is beneficial and can save a large amount of water (41%) in the cotton belt area. This also saves environment from degradation as less pesticides are used. The return per unit is more compared to the conventional cotton as it has 58.2% saving on economy.

Table 9. Comparative economic analysis of model and control fields under cotton + okra

Components	Model plot	Control plot
Total expenditure, INR	17525	19360
Total returns from production, INR	33465	29400
Net returns from production, INR	15890	10040
Number of irrigations	3	5
Total time required for crop maturity (hrs)	104	176
Total water required for crop maturity in cum	1937	3278
Water savings, %	40.91	--

Model 6. Inter-cropping System (Cotton + Moong (Vigna radiata))

Background of the research

The objective is to reduce use of pesticide and water since *moong* attracts defenders like spiders etc by providing the right soil and water conditions. *Moong* also acts as a mulch crop and it is conducive for spiders, which feed on jassids, boll borers and white flies, which are sucking pests, and therefore planting *moong* reduces pest attack on the cotton crop. Since the plant-to-plant distance is high in case of cotton and the crop remains exposed to direct sunlight, the evaporation losses from the crop are high and this needs to be checked.

The concept for making the following design was that the water losses from the interspaces between the cotton crop be checked by the cultivation of a short duration crop like *moong.* It was proposed that moong which is a leguminous crop be grown in the gaps, which would act as mulch, conserving the soil moisture during the initial stages of the cotton crop when it has smaller soil cover. The cotton crop spreads after 60 days when the *moong* has already spread. After 60-65 days, *moong* is harvested and cotton takes its place. There is an additional advantage of an extra produce from the same field. Moreover, this crop acts as a symbiotic crop and fixes nitrogen, which reduces the nitrogen requirement for the main crop.

A model Papaya garden in Kharkhara village with intercrops

Methodology

Fortnightly observations were made starting from 65 days of crop and Cotton Ecosystem Analysis (CESA) was done to see the crop growth progress for different characteristics and for comparing the model with the conventional system. Observations were taken at random for 4 replications at 109 days of crop cycle.

Observations and Results

It was observed that attack of sucking pests is less in the model as compared to the control fields (Table 10)

Table 10. Average insect counts of sucking pests under control and model plots with moong crop

Parameter	Model field with trap crop (Average count/ leaf)	Control plots (Average count/ leaf)
Jassids	0.96	1.63
Whitefly	1.60	3.42
Heliothis	0.21	0.55

Moong provided good covered area for defenders to survive and hatch eggs. These defenders reduced the pest infestation, which in turn results in reduced appearance of symptoms of yellowing and inverted cup shape of leaves, so the farmer does not use the excess water. This also acted as a cover crop to conserves soil moisture resulting in reduced water requirement for the cotton crop.
The comparative economic analysis is given under Table 11. On an average, it was found that only 3.20 irrigations were given in model plots as compared to 4.40 in control plots. Irrigation time required for crop maturity was 108 hours instead of 172 in the control. Average water usage per hectare in the model fields was 2011cum compared to 3203cum in the control fields.

Conclusions and Recommendations

This model is beneficial and can save a large amount of water in the cotton belt area. This also saves environment from degradation as less pesticides are used.

The return per unit is more compared to the conventional cotton crop. There is 37.2% water saving and 94.68% saving on economy in this model. It is recommended that this model should be adopted and replicated in the area as it saves water, ensures crop diversification, which will give an additional produce and income. Soil health can be safe guarded for a longer time due to less usage of chemicals.

Table 11. Comparative economics of suggested model (cotton+ *moong*) and control fields

Components	Model field	Control field
Total expenses, INR	17125	19360
Total returns from production, INR	38375	30275
Net returns from production, INR	21250	10915
Average number of irrigations	3.2	4.4
Total time required for crop maturity(days)	108	172
Total water required for crop maturity (in cum)	2011	3203
Water savings, %	37.2	----

Model 7. Intercropping System Arhar (Pigeon peas) + Moong (Vigna radiata)

Background of the research

The objective for this model was crop diversification i.e. to replace some of the fields grown with cotton and compare its impact on economics and water usage. The results will decide if an alternate sustainable cropping system can be established to benefit the farmers. There will also be an additional reduction in usage of pesticides, which will improve the environment and crop quality. The evaporation losses were also considered in this design as plant-to-plant distance is high in case of cotton and the crop remains exposed to direct sunlight for long hours.

Methodology

The concept for making the following design was that the water losses from the interspaces between the *Arhar* crop be checked by the cultivation of a short duration crop like *moong.*
It was proposed that *moong* which is a leguminous crop be grown in the gaps which would act as mulch, conserving the soil moisture during the initial stages of the *arhar* crop when it has sparse foliage. The *arhar* crop spreads after 60- 75 days when the *moong* crop has already spread. There is an additional advantage of an extra produce from the same field. The control field for this research was cotton. This also acts as a cover crop and conserves soil moisture, which reduces the water requirement for the cotton crop.

Observations and Results

The comparative economics of the model is given under Table 12. On an average, it was found that only 2 irrigations were given in model fields as compared to 4 in control plots. Average water usage per hectare in the model was 90 hours compared to 176 hours in the control. Average water usage per hectare in the model was 1676 cum compared to 3278 cum in the control. Net return from production in the proposed model per hectare is Rs.17, 600/- compared to Rs.10390/- under control.

Conclusions and Recommendations

Since the return per unit is more compared to the conventional cotton crop, this model is recommended for the region. There is 49 % water saving and 69% increase on economy in this model.

It is recommended that the above model be adopted in the area as the expected results were seen in reality in the models after crop harvest and the farmer can save water as well as ensure crop diversification in his field (which will give him an additional produce and improve his earnings).

Soil health can be safeguarded for a longer time due to less usage of chemicals.

Table 12. Comparative economics of model (Arhar + Moong) and control fields

Components	Model field	Control field
Total expenses, INR	13000	19360
Total returns from production, INR	30600	29750
Net returns from production, INR	17600	10390
Number of irrigations	2.4	4.6
Total irrigation time required for crop maturity(hrs)	90	176
Total water required for required for crop maturity (cum)	1676	3277
Water savings, %	48.85	----

Healthy growth of guava in the model garden of Ramnath of Kankarchaja. He has a composite fruit model of lesva, papaya, pomegranate, guava and Baelpatra

Model 8. Introduction of perennial fruit plants and vegetables in the conventional cropping system - Model Garden

Background of the research

The human body needs 280g/day per capita of vegetables while the availability in Rajasthan is only 45g. Moreover, while human beings need 120g/day/capita of fruits the availability is only 12 g. These facts have to be addressed very seriously for proper health and growth of humans so that malnutrition resulting from intake deficiencies can be controlled. Keeping these facts in mind the project made a survey of the operational area and observed that there are negligible perennial fruit trees. The area sown under vegetables was also very small. There was immense scope of expanding the area under vegetables by combining them with fruit trees.

It is a fact that water requirement for fruit trees is low compared to agricultural crops. On the contrary, we also see that the returns from the fruit trees are very high compared to the produce from the conventional agricultural crops. These factors encouraged and motivated the project to design appropriate models.

There was some initial resistance, as the farmers did not wish to keep their land fallow for fruit trees. This was addressed by having a series of meetings and discussions with individuals and groups on the advantages of having horticulture as an option over conventional cropping system in a portion of the farmers' land. Many farmers agreed to the objective. There were trained and oriented by scientists on the concept and implementation of these models.

The designs were made for the gardens, which also included economic statistics of returns over a period of the establishment of the garden. It was also ensured that the farmer gets regular returns from the model gardens right from the first year by taking seasonal vegetables in them as per the schedule given below (Table 13).

Table 13. Recommended vegetable crop rotation table for the model garden

Ladies finger (June- September)	Garlic (October- February)	Tinda(gourd) (March – May)
Tinda(July- October)	Peas(November –March)	Water melon (April-June)
Cucumber (July- October)	Carrot+ Radish (November-March)	Spinach (April-June)
Cauliflower (Early maturing) (July-September)	Cauliflower+ Green Coriander (October- February)	Ladies finger(March-June)
Brinjal+Green Chillies (July- March)	-	Spinach + Lobia (March-June)

In order to make the models sustainable and to ensure timely and healthy plant material, the project also mobilized farmers to raise nurseries on their own land for which they were trained.

50 Model Gardens were also identified and adopted by the farmers for establishing water efficient agricultural technologies

The model designs were as follows:
1. Baelpatra (Stone fruit) + lesva (Gum plant) + papaya
2. Amla + vegetable
3. Papaya + vegetable

Rajender of kakarchaja sowed Bottle Gourd in his model garden of papaya for utilization of empty land in model garden. He irrigates it through drip which is already established in the model garden**.**

Methodology

Baelpatra (Stone fruit) + lesva+ papaya

In this model, planting of Baelpatra is done on the boundaries of the garden and lesva is planted at 6m x 6m distance in the field. For every 2 rows of papaya, there is one row of lesva. The farmer will sow ladies finger (June-September) and then Fenugreek (October-March). The logic behind this combination is that Ladies' finger starts to give returns from 45 days of crop period and the farmer gets a return of 6 t/hectare (equivalent to Rs.30, 000 /hectare assuming that the farmer gets a minimum market rate of Rs. 5.00/kg for ladies finger) and a return of 1.6 t/hectare (equivalent to Rs.32, 000-/hectare assuming that the farmer gets a minimum market rate of Rs. 20/kg for Fenugreek). The total expenses incurred in the whole garden for the period of one year is approx. Rs.30, 000/-. This implies that the farmer gets a profit of Rs. 32,000/- per hectare in the very first year.

In the second year, papaya is also grown in the model gardens. The plant density for one hectare sown area for papaya plants is 1100 and in the second year, papaya starts giving the returns (Rs. 220,000/- from an average of 44 t/hectare at a minimum mandi rate of Rs.5/kg). The returns from the vegetables (ladies finger and fenugreek) continues to be the same as in the first year.

The total returns are Rs 282,000 and assuming that the total expenses in the second year are Rs 50,000 (due to additional expenses in the second year towards plant protection transportation, harvesting etc.), the farmer gets the profit of Rs 232,000. These results are given in Table 14.

Table 14. Economic analysis for the two years in the Model Gardens

Year	Ist		IInd		
Vegetables	Ladies finger	Fenugreek	Ladies finger	Fenugreek	Papaya
Productivity (t/ha)	6	1.6	6	1.6	44
Mandi Rate (Rs/kg)	5	20	5	20	5
Economic Return, INR	30,000	32,000	30,000	32,000	220,000
Total Expenses, INR	30,000		50,000		
Net Profit, INR	32,000		232,000		

Moreover, in fact the water requirement for the fruit decreases as they penetrate into the soil and take soil water. The area under vegetables will also slowly decrease water intake when the fruit plants have increased canopy. Along with reduced water usage, the net profit also increases over the period. From the third year onwards, baelpatra and lesva start bearing fruit and so the farmers get additional produce.

The practices for the other models (Amla +vegetable and Papaya+ vegetable) were also similar.

Observations and Results

From all the model gardens, we have been getting records of produce for vegetables like green chilies, tomato, brinjal, radish, carrot, garlic, coriander, fenugreek, cauliflower, bottle gourd, ridge gourd, muskmelon and cucumber. Most of the vegetables are being irrigated through Furrow Irrigated Raised Bed method to ensure 50 % water saving.

Since it is just one year that the gardens are established, the statistics are available only for this period, but from the observations we are very optimistic to get expected results as per the plan made for the subsequent years.

Conclusions and Recommendations

From the various interactions with the model farmers and their responses to others in field days and the positive attitude shown by them, there are signs of increased adoption of the model garden in the future. More farmers are coming to know the designs and understand about the benefits and many of them have also signed up for the experiments in the coming year.