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Irrigation Efficiencies: Practical Difficulties and Measures for Its Improvement

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Abstract : Efficiency concept in any system is based on a measures of output obtained from a given unit of input. In agriculture, efficient water utilization reflects how efficiently water is stored, distributed and used in crop production. The design of the irrigation system, the degree of land preparation and the skill and care of the irrigator are the principle factors influencing water use efficiency. In a well designed irrigation system, on-farm efficiency in surface methods of irrigation ranges from 60 to 70 percent and in sprinkler irrigation, 70 to 80 per cent. Most of the Irrigation Projects throughout the world functioning on the principle of gravity flow operate with 25 – 40 percent efficiency.

In this paper various irrigation efficiencies are explained theoretically with example. However, these all calculations require precise pre-recorded water release / application data in the command area at various points which are almost not available in most of the irrigation projects. Hence alternate strategy for working out water productivity is recommended to evaluate the performance of irrigation project with a case study.

IRRIGATION EFFICIENCY

Irrespective of the method of irrigation, no method or system of irrigation is 100 percent efficient and not all the water that is applied during any irrigation enters the soil and is held in root zone. Very often, reasons for poor efficiency are beyond control of irrigator as well as project authorities, as some unavoidable losses do occur due to seepage and leakages in conveyance system, non uniform distribution of water in the field, percolation below root zone and wastage due to surface runoff at the end of the field. In surface irrigation systems, water losses at various stages are estimated at 30 – 35 % in field as well as in conveyance system.

High efficiency is not possible by surface irrigation unless lands are perfectly leveled and prepared for efficient on-farm water application for irrigation besides strict control on water releases. In many areas, specifically in water deficit state of Gujarat, increased efficiency would result in increased irrigated acreage as well as decreased problems of salinity and drainage. Irrigation efficiency indicates as to how efficiently the available water is being used based on different methods of evaluation. Design of irrigation system, O & M of irrigation system, degree of land preparation with skill and care of irrigator are the principle factors influencing the efficiency.

The water losses generally occur in

- conveyance system through seepage and leakages
- non uniform distribution of water over the field
- percolation below root zone
- evaporation from sprays of sprinklers and retention of water on foliage
- evaporation from local depressions in fields & runoff at the end of fields

These losses can be minimized by adequate planning, design and management of methods, adequate land preparations using latest

technologies, besides efficient operations of irrigation system with some control on water release in the canal system. Irrigation efficiency can be divided in to three parts as under:

Off-farm efficiency/ Water Conveyance Efficiency (Ec)

Also called Water Conveyance Efficiency, it is the ratio of output to input. This efficiency is associated with the canal network and is expressed as;

$$\text{Water Conveyance efficiency} = \frac{\text{Water delivered by network at field inlet}}{\text{Water delivered from the system}} \times 100$$

Primary factors affecting conveyance losses are Physical condition of system, Design aspects of main system & field system and operational practices.

On-Farm Efficiency

Once the water has reached at mouth of the crop field, it is important to apply water as efficiently as possible. Following terms are defined in connection with on-farm efficiency:

a) Water application efficiency (Ea)

Water application efficiency is the ratio of water stored in the root-zone to the total water delivered to the field.

$$\text{Water application efficiency} = \frac{\text{Water stored in the root zone during irrigation}}{\text{Water delivered to the field}} \times 100$$

An under irrigation may result in 100 percent water application efficiency, but this will not be a good practice in the long run because cumulative water deficiency would result in lowered crop yields.

b) Water storage efficiency (Es)

The concept of water storage efficiency gives an insight to how completely the required water has been stored in the crop root zone during irrigation.

$$\text{Water storage efficiency} = \frac{\text{Water stored in the root zone during irrigation}}{\text{Water needed in the root zone prior to irrigation (field capacity – existing moisture content)}} \times 100$$

c) Water distribution efficiency (Ed)

Water distribution efficiency evaluates the degree to which the water is uniformly distributed throughout the root zone, it is defined as;

$$Ed = 100\,(1 - Y/D)$$

In which Ed = Water distribution efficiency;
D = Average depth of water stored during the irrigation
Y = Average numerical deviation from D

The efficiency values represent the water distribution relative to the entire field and not relative to each crop row or furrow. The more uniformly the water is distributed, the better will be the crop response. Uneven distribution has many undesirable effects.

Other Efficiency

Water use efficiency (WUE)

Water use efficiency is usually defined as crop production per unit of water used.

$$WUE = \frac{\text{Crop Yields per unit area}}{\text{Depth of Water loss in ET per unit area during the crop growth period.}}$$

Water use efficiency is usually expressed as kilogram of dry matter of marketable products per hectare- centimeter of water evapo-transpired. Crop yield can be greatly increased by favourable combination of soil, crop and water management practices along with proper plant protection measures. Some workers have defined the water use efficiency is the ratio of crop yield to its total water requirement and not only its consumptive water use.

Project efficiency (Ep)

The efficiency indicates the effective use of irrigation water in crop production. It is the percentage of irrigation water that is stored in the soil and is available for consumptive use by crops. When the delivered water is measured at the farm head gate (or well) it is called *farm irrigation efficiency*, when measured in the field it is designated as *field irrigation efficiency* and when measured at the points of diversion from canal or the main source of supply it may be called as project efficiency.

Water Stored in root zone
Project Efficiency Ep = x 100
Water delivered at the source

PRACTICAL DIFFICULTIES FOR WORKING OUT IRRIGATION EFFICIENCY

Irrigation Engineers are constant trying to supply irrigation water to each farmers of command area. Finally, after completion of season, they have only water release data normally at head regulator of dam site and sometimes at block level. They are have data of total water released during one season for all the crops, how much area is irrigated for each crop & for all crops. However, no data are available for individual crop that consumed water. With this data, we can calculate area irrigated by unit of water i.e. duty achieved in Ha/Mcft or Ha/Mcum of water but from economic point of view this is not sufficient. For this, at least we require crop productivity data for all irrigated crops in each project area.

WATER PRODUCTIVITY

Up till now we have heard about crop productivity (kg/ha.), animal milk productivity (liters/animal), mileage of vehicle (km/liter of petrol or diesel), labour efficiency (works/hour or day) but we hardly hear about water productivity i.e. agricultural production in terms of rupees over applied unit of water. Water use efficiency is different from water productivity. Efficiency concept in any system is based on output obtained from a given unit of input, but in water productivity we are counting output in terms of rupees rather than quantity of produce, whereas in WUE we are considering quantity produced by unit volume of water. High irrigation efficiency means maximum productivity of water and therefore, our main focus should be on higher net profit by agricultural production from unit volume of applied water. In nutshell, we can say that water productivity is a broad concept and it covers all other efficiency in water resources management because higher net return is only possible when farmers are able to produce good quality and high quantity with less amount of water which reflects upon agro-technology used by farmers, market price and water application techniques.

A theoretical calculation of water productivity of important irrigated crops is given in *Table-1*. The crop water requirements are considered at farm gate. However, water productivity given in *Table-1* depends on farmers skill, soil type, seasonal variations, marketing price etc. If water is a constraint, farmers can choose the low water consuming crops like cumin and coriander to get maximum return over applied water.

The cropped area, crop production and crop productivity data are worked out and forecasting by Director of Agriculture for each crop grown in respective states are based on crop cutting survey carried out by Department irrespective of command area and irrigation sources, Hence, Irrigation Engineers cannot use this data for calculation of water productivity in the project. Project-wise crop productivity data is required and for this, neither irrigation department nor agriculture department is collecting project-wise crop productivity data. With lack of crop productivity data, we can not workout water productivity for individual project. Therefore, efforts have been made to work out strategy for this by which irrigation authority can assess the

Table 1. Water productivity of important irrigated crops of Gujarat on the bases of theoretical data

Sr. No.	Particulars	Information to fill-up by Farmers/WRD		
A	***Project Information***			
1	Name of irrigation project			
2	Name of Division / Sub Div. / Minor No.			
B	***Farmer's Information***			
1	Name of Farmers			
2	Name of Village / Taluka / District			
3	Survey No. of Farm			
4	Cultivated Area of Survey No. (Ha.)			
C	***Crop Information***			
1	Year / Season			
2	Name of crop / variety			
3	Crop area (Ha.)			
4	Date of sowing / Method of sowing			
5	Whether Seed treatment given? (Yes / No)			
6	Seed rate (Kg/ha.)			
7	Fertilizer applied	Name of fertilizer	Date of application	Quantity of fertilizer
	a. Organic fertilizer / FYM			
	b. Chemical fertilizer			
8	Irrigation by Canal Water • Outlet flow rate : _____LPS	No. of Irrigation	Date of Irrigation	Time in hours
		1		
		2		
		3		
		4		
		5		
9	Irrigation by other sources • Name of source : _____ • Flow rate : _____LPS	No. of Irrigation	Date of Irrigation	Time in hours
		1		
		2		
10	Date of crop cutting			
11	Yield Kg/Crop area			
12	Yield Kg/Ha			
13	Date of visit & place with signature			
14	Signature of Farmer			

Form-A

Specimen Format for collection of data from farmers to assess crop productivity in canal command area.

Sr. No.	Particulars	Information to fill-up by Farmers/WRD		
A	***Project Information***			
1	Name of irrigation project			
2	Name of Division / Sub Div. / Minor No.			
B	***Farmer's Information***			
1	Name of Farmers			
2	Name of Village / Taluka / District			
3	Survey No. of Farm			
4	Cultivated Area of Survey No. (Ha.)			
C	***Crop Information***			
1	Year / Season			
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6	Seed rate (Kg/ha.)			
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	a. Organic fertilizer / FYM			
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		1		
		2		
10	Date of crop cutting			
11	Yield Kg/Crop area			
12	Yield Kg/Ha			
13	Date of visit & place with signature			
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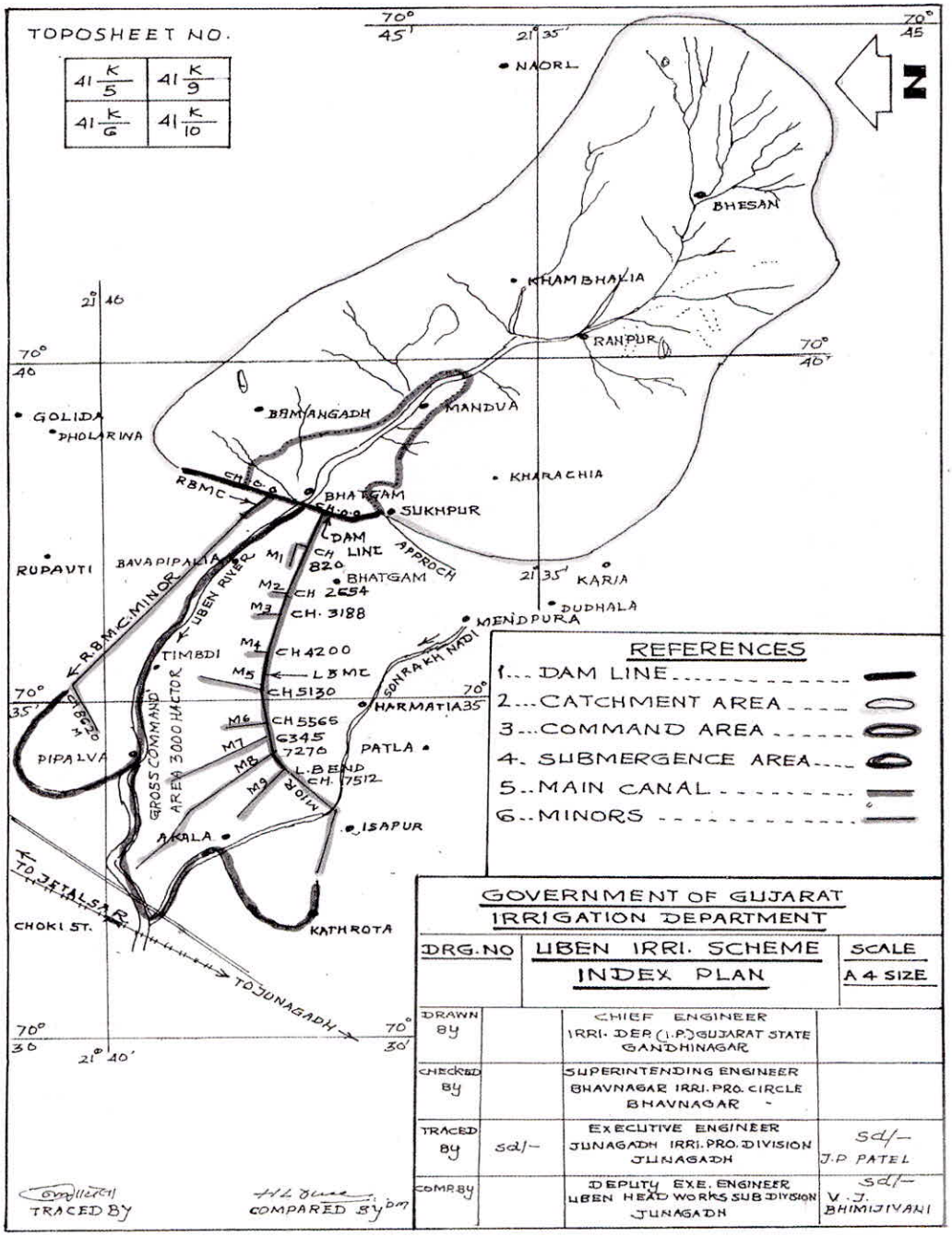

Fig. 1. Paper on Irrigation Efficiencies(DKD)WALMI-Anand Bhatt/02112011

crop productivity by using data which is fill up in prescribed format (Form-A) by farmers contact survey with the help of Agriculture Department or WALMI with minimum efforts.

METHODOLOGY FOR CROP PRODUCTIVITY DATA ASSESSMENT BY FARMERS CONTACT SURVEY IN CANAL COMMAND AREA

1. Select randomly at least one or two farmers from each minor of irrigation project
2. Handover the Form-A to selected farmers well in advance i.e. before sowing.
3. Monitor and verify that the farmers are filling information properly or not.
4. Consult VLW/Agriculture Officer, if required, in crop yield survey and collect the Form-A from all farmers after crop cutting.
5. Calculate the crop productivity for individual crops on the bases of farmers contact survey data fill up in the Form-A.
6. Form-A also contains other data on Agro-technology adopted by farmers and it will help to judge the crop productivity data.
7. Here we are collecting data from entire area viz: head reach, middle reach & tail command and therefore, the collected data are highly useful to compare water productivity in different parts of command area which can be useful to further improve in next coming season.

CASE STUDY FOR WATER PRODUCTIVITY

Three Irrigation Projects Viz., Uben, Jhanjesari and Munjiyasar in Saurashtra region were selected for working out crop productivity and water productivity. The brief details of irrigation projects are as under;

Due to erratic and uneven rainfall pattern it is very difficult to get sufficient water available for irrigation in most of the Saurashtra region but fortunately in the year 2010, most of the irrigation projects were filled up and adequate water was available for irrigation in *Rabi* season of 2010-11. Therefore, above three projects were selected for working out crop and water productivity to know the performance of irrigation projects.

Sr. No.	Particulars	Brief details of Irrigation Project		
		Uben	Jhanjesari	Munjiyasar
1	Name of Taluka	Bheshan	Visavadar	Bagsara
2	Name of District	Junagadh	Junagadh	Amreli
3	CCA in Ha.	2500	1653	1700
4	Nos. of Beneficiary Villages.	08	10	09
5	Live Storage Capacity in Mcum.	15.60	09.80	13.60
6	Canal System			
	a. Main	Lined	Un-Lined	Lined
	b. Distributory	Lined	Un-Lined	Un -Lined
	c. Water Courses	Lined	Un-Lined	Un-Lined
7	Soil Type of CCA.	Sandy clay with jental sloppy topography	Sandy clay with muram and hilly topography	Silty clay to clay soils with flat topography
8	PIM Status (CCA covered in %)	100	25 - 30	60 – 70

The prescribed methodology was adopted for collecting crop details from farmers and sample calculation in detail is given for Uben Irrigation Project in Table-2A, 2B and 2C. Similar process was followed for other two irrigation projects. The comparative data and information are given in Table-3 for above three irrigation projects.

RESULT AND DISCUSSION

Data on crop productivity collected from farmers and water released data available with the irrigation authority are presented in Table-3 for above three irrigation projects. Based on available data duty, delta, crop productivity and water productivity are worked out and discussed as under :

Duty / Delta

Table-3 indicates that the highest duty (36.29 Ha/Mcft) was achieved in Uben Irrigation Project and it may be due to lined canal system up to farmer's field with sloppy soils topography and highly progressiveness of farmers. Farmers has utilized only 75mm delta (water depth) at HR for one irrigation which is scientifically required normally at field level, i.e. conveyance efficiency is very high and overall project efficiency is excellent. All farmers are members of WUAs and they feel that the irrigation management is our responsibility and they are having sense of ownership and adoption of RWS water distribution resulting in economic water utilization. The lowest duty was recorded in Jhanjeshari Project because of undulating topography, light texture soil with muram and unlined canal network. Moreover farmers are not willing to form WUAs and only 25-30% CCA has been covered under WUAs. The delta at HR is 140mm for one irrigation which hardly reached at farmer's field @ 70mm depth though it was not measured. The duty achieved in Munjiyasar Project is about 29.35 Ha/Mcft and depth of one watering is 96mm at HR. Looking to the topography and soil texture, at least 80mm water depth is required for one irrigation and against this 96mm water has been released from HR. By this way, we can say project efficiency is about 80%.

Crop Yield

Wheat is the principle crop in all projects and hence comparison of wheat yield is given here after. The highest wheat yield (4792 Kg/Ha) was harvested in Uben Project followed by 3794 Kg/Ha in Jhanjesari and 3259 Kg/Ha in Munjiyasar Project. Farmers of Uben Project are highly progressive which adopted all latest scientific technology whereas in Munsiyasar Project wheat yield is very less due to delayed sowing with imbalance fertilization even though soils are highly conducive for wheat crop.

Water Productivity

Agriculture is a dynamic activity which is affected by a number of parameters and it would be very difficult to arrive at one conclusion. howerver water productivity is very appropriate indicator which reflect up to which level water is converted in to rupees by producing 5F (Food, Fodder, Fuel, Fiber & Flowers) on farmers field. The highest water productivity has been worked out in Uben Project @ Rs. 10.81 by utilizing one cubic meter of water at head regulator of dam and it was lowest in Munjiyasar Irrigation Project @ Rs. 5.52.

SUGGESTIVE MEASURES FOR IMPROVEMENT IN IRRIGATION EFFICIENCY

- Water should be considered an economic good with a value reflecting its most potential use. It should not be a free good as at present.
- Water Resources should be managed at the lowest appropriate level (farmers) with greater public participation.
- Incentives should be given to farmers who use water economically as there is no advantage or benefit now for him from saving water though it helps the nation.

Table 2. Sample Calculation of Crop and Water productivity in Uben Irrigation Project on the basis of Data collection from Farmers by Sample Survey (Season: Rabi 2010-11)

Sr. No.	Water Course No.	Survey No.	Name of Farmer	Crop productivity (Kg./Ha.)		
				Wheat	Cotton	Onion
1.	LB -M1	128/1	Ravaji Mohan	5250	--	-
2	LB -M1	129/3	Hasmukh Kadava	5000	-	-
3	LB -M1	112/1	Gopal Valji	5250	-	-
4	LB -M2	44 p	Durlabhi Kuraji	5000	-	-
5	LB -M2	67	DBhikha Hira	5625	-	-
6	LB -M2	5 / 1	Jayni Govind	5000	-	-
7	LB -M3	56	Rajesh Mohan	-	2500	-
8	LB -M3	51/1	Shambhu Jaga	3750	2500	-
9	LB -M3	74	Vallabh Popat	3750	2500	-
10	LB -M4	2 / 1	Narshi Dungar	5000	-	-
11	LB -M4	10 / 2	Babu Bechar	4750	-	-
12	LB -M4	142	AshokVashram	5250	-	-
13	LB -M5	279	Chanu Daya	4875	-	-
14	LB -M5	261 /1	Jaman Samji	5250	-	-
15	LB -M5	191	Champaben Keshav	5125	-	-
16	LB -M6	235/5	Mansukh Ravaji	5000	-	-
17	LB -M6	294 / 1	Mulaji Kachara	5000	-	-
18	LB -M6	263	Ramesh Kanji	4750	-	-
19	LB -M7	273	Ramnik Jamnadas	-	3500	-
20	LB -M7	229 / 1	Chiman Mohan	4375	-	-
21	LB -M7	259 / 1	Kana Naran	3750	-	-
22	LB -M8	49 /2	Shambhu Bhagavan		-	17500
23	LB -M8	78 /4	Manshukh Bhagavan	4375	-	-
24	LB -M8	68 / 1	Parsotam Jeram	4500	-	-
25	LB -M9	29 p	Hansaben Bhagavanji	-	3375	-
26	LB -M9	74	Bhanu Gordhan	-	2500	-
27	LB -M10	41 / 1	Bhikha Lakhman	4375	-	-
28	LB -M10	54 / 4	Rekhaben Sailesh	5000	-	-
29	LB -M10	51 / 2	Gokal Hira	4375	-	-
30	RB -M1	172 /5	Chandulal Vashram	5000	-	-
31	RB -M1	105 / 1	Bipin Devashi	5000	-	-
32	RB -M1	30 / 1	Gordhan Narshi	5000	-	-
			Average	**4792**	**2812.5**	**17500**

Table 2A. Crop Productivity of major crops grown in Rabi 2010-11 in Uben Project.

Sr. No.	Name of Crops	Total Area (Ha.)	Productivity (Kg./Ha.)	Total production (Kg.)	Price Rs./Kg.	Total value (Rs.)
1	*2*	*3*	*4*	*5*	*6*	*7=5x6*
1	Wheat	661	4792	3167512	12	38010144
2	Cotton	120	2812.5	337500	50	16875000
3	Charo	61	43750	2668750	1	2668750
4	Tal	76	1250	95000	50	4750000
5	Onion	83	17500	1452500	5	7262500
Total.....						**69566394**

Table 2B. Value of Agriculture Production in Uben Irrigation Project.

Water Utilization in M^3		Total Water Utilization (M^3)	Value of Total Agricultural production (Rs.)	Water productivity (Rs./M^3)
Canal Water at HR	Approximately well water @ 10% of Canal water			
1	*2=1x0.10*	*3=1+2*	*4*	*5=4/3*
5848000	584800	6432800	69566394	10.81

- The extension machinery of the irrigation department which supply water and maintain canal system should have very close co-operation with the extension agencies which operate to increase the agricultural production on the farmer's fields.
- Water management practices for each crop should be transmitted to the farmers through demonstration, by holding meetings of groups of farmers of the outlet.
- There should be water management Training Center in each command area that will impart training to the farmers periodically.
- Water Co-Operatives to regulate distribution of canal water in the outlet command should be promoted.
- Conjunctive use of canal and underground surplus water observing quality of water, sub-soil water table, soil salinity and change in the chemical and physical properties of the soil should be periodically recorded and steps taken immediately when deterioration conditions deteriorate.
- Canal water should be given to farmers on volumetric bases rather than area bases.

Table 3. The comparative data and information of Uben, Jhanjesari and Munjiyasar Irrigation Project.

Sr. No.	Particulars	Name of Irrigation Projects		
		Uben	**Jhanjesari**	**Munjiyasar**
1	Canal Water Utilization			
a.	Water released at HR (Mcft)	206.52	148.99	161.46
b.	Total Ha. Watering	7495	3000	4739
c.	Duty achieved at HR (Ha/Mcft = b/a)	36.29	20.20	29.35
d.	Delta at HR one watering in mm (2832/c)	78	140	96
2	Cropping Pattern and area in Ha. (with crop productivity Kg/Ha)			
a.	Wheat	661 *(4792)**	439 *(3794)*	677 *(3259)*
b.	Cotton	120 *(2812)*	37 *(3125)*	--
c.	Fodder	61 *(43750)*	--	--
d.	Tal	76 *(1250)*	--	--
e.	Onion / Garlic	83 *(17500)*	23 *(8250)*	--
	Total Area Irrigated	1001	499	677
3	Total Value of Agril. Production in Rupees.	69566394	34306792	26476116
4	Total Water utilization in M3 (Canal + Well)	6432800	4556520	4800600
5	Water Productivity (Rs. / M^3 of Water)	10.81	7.53	5.52
6	Technology adopted by Farmers for			
a.	Date of Sowing	Normal	Normal to Late	To Late
b.	Fertilizer	Balance and Recommended	Recommended Fertilizer	Only Nitrogen Fertilizer
c.	Pesticides	Applied	Applied	Not Applied
d.	Farmers Progressiveness	Highly Progressive	Progressive	Progressive

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