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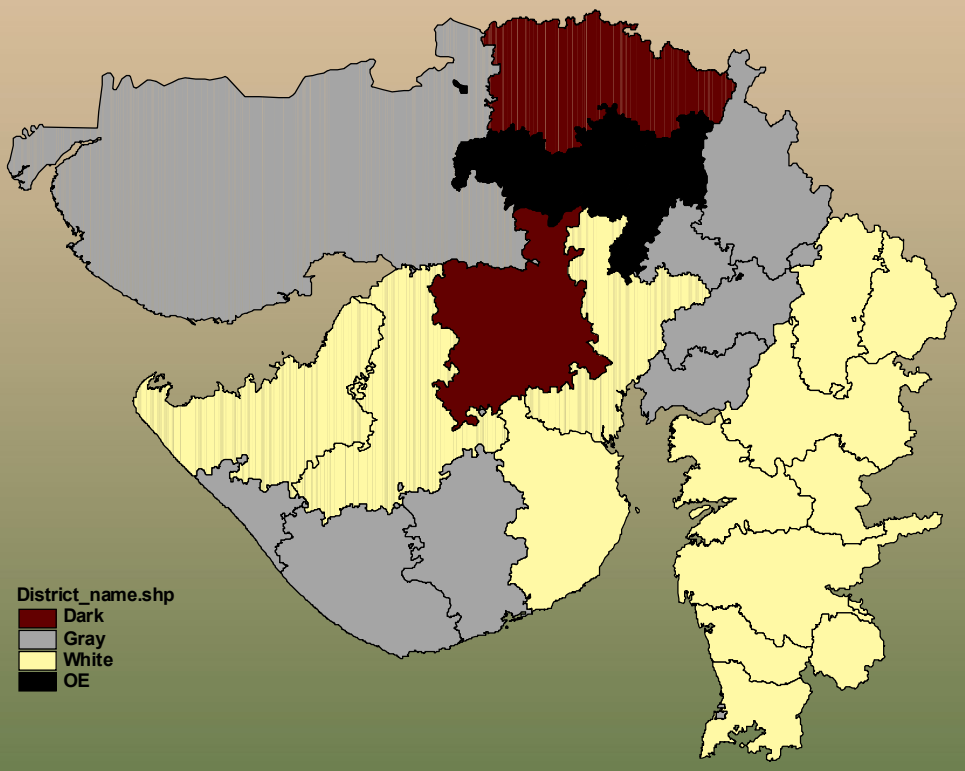
Water Management Technologies – A Compilation

(1980 to 2012)



Soil and Water Management Research Unit,
Navsari Agricultural University
Navsari- 396 450

2012

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Water Management Technologies – A Compilation

(1980 to 2012)

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2012

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PREFACE

The state of Gujarat has a wide variety of soil, climate, cropping patters and extent of water availability and its' quality. It is, therefore, implicit that each and every situation arising out of various combinations of the factors above would require separate technological inputs. On account of such varied situation, location specific water management technologies for different crops have been developed at the research stations/ zonal stations located in different agro ecological situations of the state. The information provided in this publication gives detail account of water resources available in state, quality of waters and water management technologies including drainage developed for Gujarat. This publication also contains success stories of MIS and subsurface drainage which indicate adoption of water management technologies on large scale by the farmers. The information compiled in this publication will be of great help to the planner, policy maker, GGRC, scientists, students and farmers. I commend the efforts put in by team of the scientists in bringing out this publication.

Place: Navsari
Date: 2 / 10 / 2012

(A. N. Sabalpara)
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FOREWORD

Gujarat being a water scarce state, lot of emphasis is put on augmentations of water resources through farm ponds, check dams, river linking *etc*. Under the circumstances, it is of prime importance that the water available for agriculture uses is to be utilized in most efficient way. In this context, Soil and Water Management Research Unit, Navsari Agricultural University, Navsari is in forefront in the research on different aspects of water management in Gujarat. This trend is still continued even after the formation of four agricultural universities in the state. The information related to water management is generated by different research stations/zonal research stations which subsequently passed on to the Director of Agriculture, Director of Horticulture, WALMI, pertinent NGOs and the farmers. The technologies available till date for scheduling of surface method of irrigation, scheduling of irrigation and fertigation through drip and sprinkler, mulching *etc*., have been compiled in this bulletin. Not only this, but the bulletin also contains a chapter on subsurface drainage, an integral part of water management. In order to know the impact of water management technologies, success stories of micro irrigation and sub surface drainage are also incorporated in this bulletin. I sincerely hope that, this bulletin will be of immense help to the planner, policy makers, GGRC, students, scientists and farmers. I congratulate the team of scientists who have timely brought out this informative bulletin.

Place: Navsari
Date: 02/10/2012

(A. R. Pathak)
Vice Chancellor

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The co-operation received from the following authorities/ organizations/ scientists at various stages of implementation of soil and water management research programs in Gujarat is gratefully acknowledged.

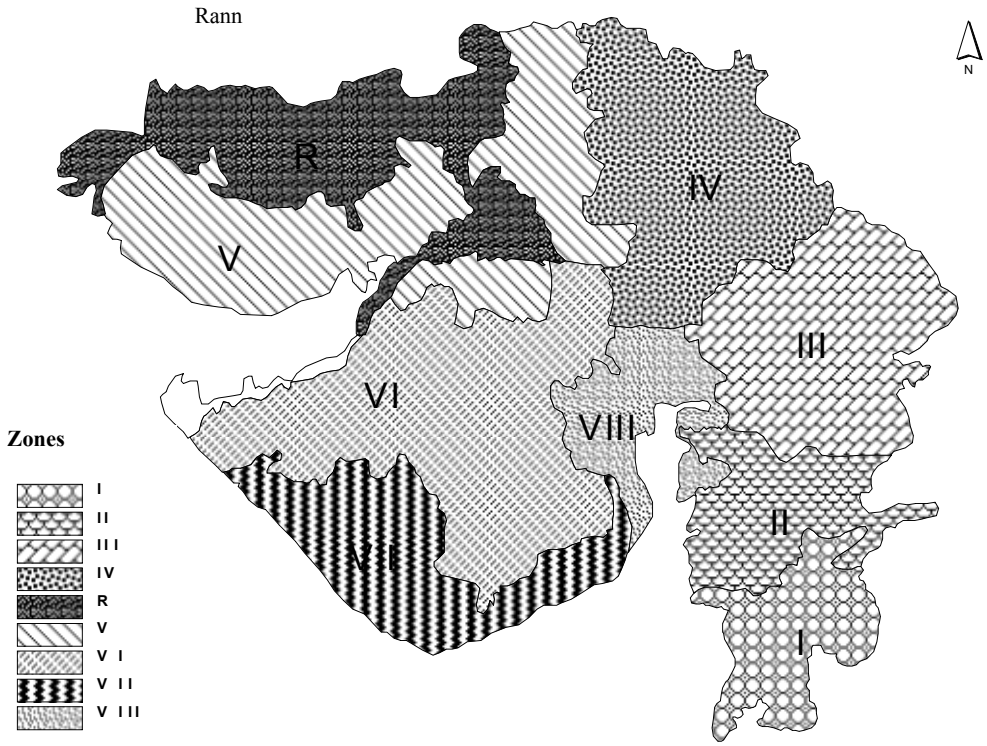
1. Vice Chancellor, erstwhile GAU, S.K. Nagar
2. Director of Research, erstwhile GAU, S.K. Nagar
3. Vice Chancellor, NAU, Navsari
4. Director of Research, NAU, Navsari
5. Deputy Director General (NRM), ICAR, New Delhi
6. Commissioner, Horticulture, GoI, New Delhi
7. Assistant Director General (WM), ICAR, New Delhi
8. Director, Coordinating Unit of Water Management, WTCER, ICAR, Bhubneshwer
9. National Committee on Use of Plastics in Agriculture and Horticulture, GoI, New Delhi
10. Narmada and Water Resources Department, GoG, Gandhinagar
11. Superintendent Engineer, Drainage, Surat
12. Executive Engineer, Ambi Division, Navsari
13. All the staff members of Soil and Water Management Research Unit, NAU, Navsari
14. All the scientists who have contributed to the development of technologies

Editors

CONTENTS

I. INTRODUCTION

The state of Gujarat is western most part of the country, and lies between 20° 10' and 24° 7' N latitude and 68° 40' and 74° 4' E longitude covering an area about 196 thousand km^2 and furnishes a mosaic of geologic, physiographic, soil and climatic variation. These diversities are further accentuated as the state possess longest sea coast of 1600 km. The heterogeneity in rainfall is evident from less than 500 mm in Kutch to as high as 2000 mm in the Dangs with annual average of 828 mm in the state (Raman *et al.,* 2000). Based on these diversities, the state has been divided in to eight agroclimatic zones *viz*., I) South Gujarat heavy rainfall, II) South Gujarat, III) Middle Gujarat, IV) North Gujarat, V) North – West Gujarat, VI) North Saurashtra, VII) South Saurashtra and VIII) *Bhal* and Coastal (Fig. 1). Thus availability of water resources and its related constraints vary considerably from one location to another in the state. The agroclimatic zonewise soil related water management constraints are enumerated in table 1. Subsequently, based on agroclimatic conditions including length of growing period, the National Bureau of Soil Survey and Land Use Planning, Nagpure has identified 20 agro ecological regions in India. Of these, in Gujarat 8 Agro ecological sub regions have been identified falling under 3 ecosystems *viz;* arid, semi arid and coastal (Fig. 2).



Source: Anon. (1988 – 89)

Fig. 1: Agro climatic zones of Gujarat (NARP)

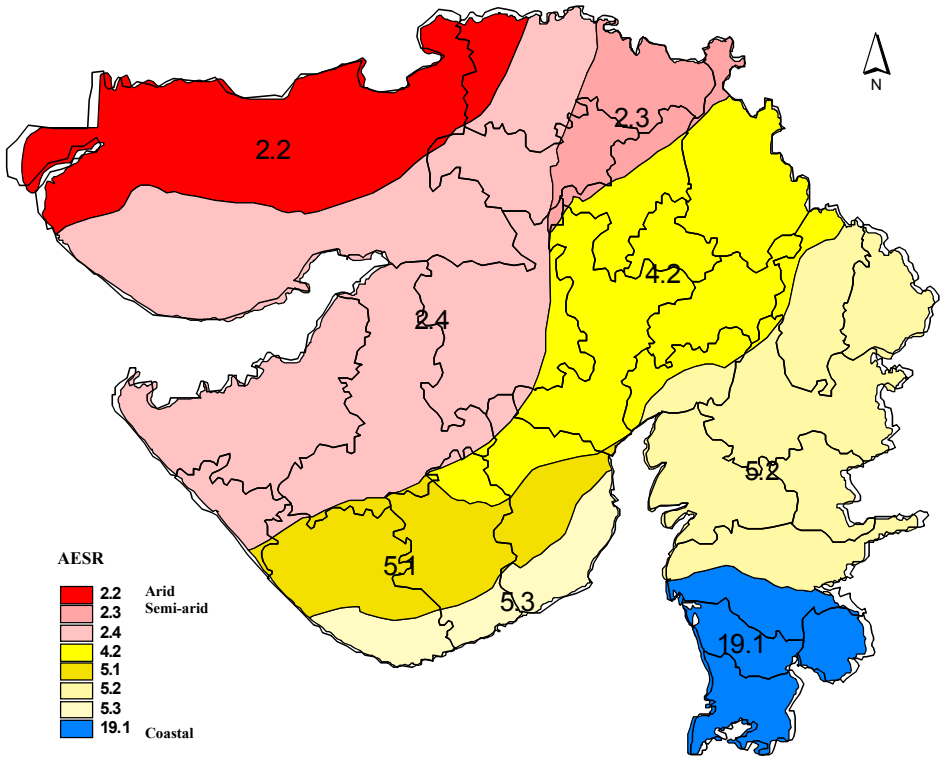


Fig. 2: Agro ecological sub regions of Gujarat (NBSS and LUP, Nagpur)

Source: Velayutham *et al.* (1999)

Table 1: Agrocliamtic zonewise soil related water management constraints

Agroclimatic zone	Physiographic location	Predominant sub-order association	Constraints
I. South Gujarat heavy rainfall	-Piedmont slope and valley plains	Ochrepts	- Shallow depth, highly erosive, low to moderate MHC, highly permeable
	-Mid alluvial plains	Ochrepts-Usterts	- High MHC, severe cracking, low to very low permeability, poor internal drainage, secondary salinization and water logging in parts
	-Coastal alluvial plains	Aquepts-Ochrepts	- Salt affected, highly dispersive, poor drainage, low permeability, mild cracking
II. South Gujarat	- Piedmont slope and valley plains	Ochrepts	- Highly errosive, low to medium MHC, highly permeable
	- Alluvial plains	Usterts-Ustochrepts	- Prone to erosion, moderate to poor drainage, medium to low permeability, secondary salinization and water logging in parts
	-Coastal alluvial plains	Aquepts, Ochrepts	- Same as those of coastal alluvial plains of zone I
III. Middle Gujarat	- Eastern hilly belt	Orthents-Ochrepts	- Prone to erosion, low MHC, shallow depth
	-Mid alluvial plains	Fluvents-Usterts	- Erosion adjoining river beds, secondary salinization and water logging in canal command areas.
	- Coastal plains	Orthids, Argids, Aquents	- Salt affected poor to medium drainage
IV. North Gujarat	- Border high lands	Orthents, Ochrepts	- Highly erodible, deep with low MHC, excessively drained.
	- Mid plains	Fluvents, Psamments, Ochrepts, Orthids	- Low MHC, salinity, excessive permeability, very low AMC
	- Western plains	Argids, Aquents,	- Salt affected, low permeability, poor drainage in some pockets

		Psamments, Usterts (in pockets)	
V. North-West	- Eastern plain	Orthents, Aquepts, Psamments, Ochrepts	-Excessive permeability, poorly drained and salt affected in pockets, low MHC and AMC
	- Western plains	Orthids, Argids, Psamments	-Poorly drained and hydromorphic in pockets, salt affected, low to medium MHC
VI. North Saurashtra	- Southern plains	Orthents, Ochrepts, Orthids, Psamments (in pockets)	- Highly calcareous, salt affected soil in patches, erodible in hilly areas
	- Northern plains (Including hilly areas)	Orthents, Ochrepts	- Low to medium MHC, Calcareous
	- Coastal belt	Orthids, Orthents, Ochrepts	- Salt affected
VII. South Saurashtra	- Inland areas (Including hilly areas)	Orthents, Ochrepts,	- Highly calcareous, poor permeability poor MHC in hilly areas
	- Coastal areas Including Ghed)	Usterts	- Salt affected highly dispersive and water logged in Ghed
VIII. *Bhal* and Coastal area	- Whole zone	Usterts, Ochrepts Aquepts, Argids	- Salt affected, poor drainage, water logging in monsoon

Source: Anon. (1988-89)

Surface and ground water potentials in the state

Gujarat is endowed with many rivers, some of which are perennial while many of them are seasonal. The perennial large rivers like Narmada, Tapi, Mahi and small ones like Daman Ganga are flowing in the South and Central Gujarat. On the other hand, in North Gujarat the rivers are not only few but also seasonal in flow. Sabarmati, Banas, Rupen and Saraswati are the important ones (Fig. 3).

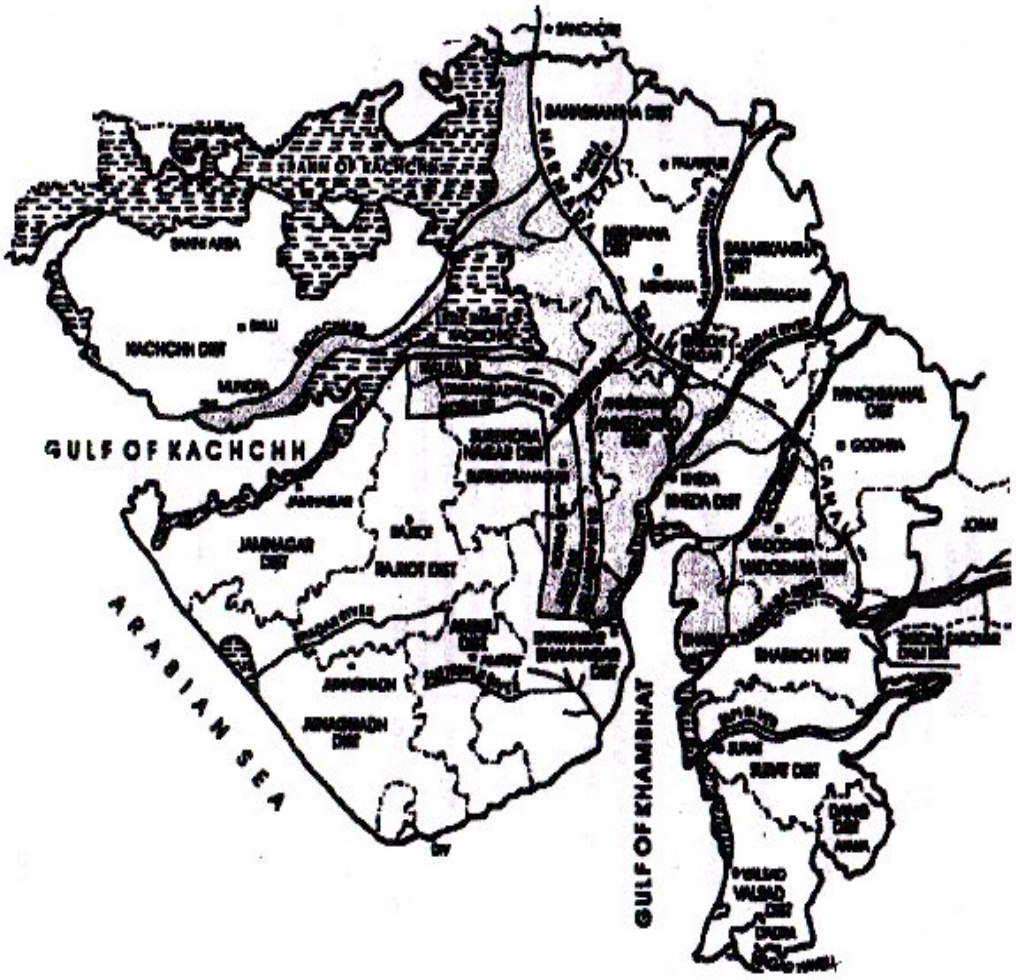


Fig. 3: River basins of Gujarat

The total surface water potential of the state is 38.5 thousands MCM of which 32.3 thousands MCM is contributed by South and Central Gujarat (Table 2), while only 2 thousand MCM comes from North Gujarat. The ground water potential is only 16

thousands MCM. Though, the combined contribution of South and Central Gujarat is the maximum but unlike the surface water potential wherein the contribution from this region is 84 per cent, in case of the ground water potential the contribution is only 35 per cent. Thus, out of the total water potential of 54.5 thousands MCM about 38 thousands MCM is contributed by the South and Central Gujarat working out to a percentage of 70. The corresponding percentages for North Gujarat, Saurashtra and Kutch are 6.1, 9.2 and 1.2, respectively.

Table 2: Surface and ground water potentials of Gujarat ('000 MCM)

Region	Surface Water	Ground Water	Total
South and Central	32.3	5.7	38.0
North Gujarat	2.0	4.1	6.1
Saurashtra	3.6	5.6	9.2
Kutch	0.6	0.6	1.2
Total	**38.5**	**16.0**	**54.5**

Source : Anon.(2000)

Out of the 54.5 thousand MCM /yr of available water 19.1 thousand MCM is being utilized (Table 3). Among the different regions, the utilization was lowest in South and Central Gujarat (18%) though the actual usage is highest (7.0 thousand MCM/yr). On the other hand, in North Gujarat, where the availability is 6.1 thousands MCM/yr, the utilization is 6.0 thousand MCM (98 %). In other words, all the available waters are almost utilized in this region. The utilization in Saurashtra and Kutch are 59 and 58 per cent, respectively.

Table 3: Water utilization in Gujarat ('000 MCM)

Region	Utilization	% of the state	% of total availability
South and Central Gujarat	7.0	36	18
North Gujarat	6.0	31	98
Saurashtra	5.4	29	59
Kutch	0.7	4	58
Total	**19.1**		**50**

Source: Srinivas Mudrakartha (2004)

Irrespective of the sectors during the year 2000, the total water requirement of the state was estimated to be around 29.43 thousand MCM which is estimated to rise to 36.5 thousand MCM during 2010, 46.86 thousand MCM during 2020 and 53.1 thousand MCM during 2025 registering an increase of 80 per cent (Table 4). At the state level, the maximum contribution for the per cent increase is from industry, which is estimated to draw 736 per cent more water than existing water utilization in 2000. This is followed by the demand for domestic use with a percentage increase of 165.

The water requirement for agriculture, which was 93 per cent during 1997, will be going down steadily and it will contribute to 82 per cent of the total water requirement by 2025. This reduction is mainly due to increased demand from other sectors and not due to reduction in the quantity of water required in agricultural sector. In fact by 2025, the state needs 16 thousand MCM more water for agriculture use.

Table 4: Water requirements for different sectors

Sector	Water requirement(MCM)				
	1997	**2000**	**2010**	**2020**	**2025**
Domestic	1374	1545	2288	3618	4103 (165)
Industrial	448	644	1505	3522	5386 (736)
Livestock	224	230	239	263	284 (23)
Agriculture	25672	27013	325151	39352	43306 (60)
Total	**27616**	**29431**	**36558**	**46769**	**53088 (80)**
%Agriculture	93	93	90	84	82
%Domestic	5	5	6	8	8
%Industry	2	2	4	8	10

Figures in parenthesis shows per cent variation over 2000 *Source: Anon. (2000)*

Ground water development

During 1997, out of the 16 thousand MCM of ground water recharge at the state level, it was estimated that about 13 thousand MCM was estimated to be utilizable recharge. About 9.7 thousand MCM was estimated to be the draft leaving around 3.1 thousand MCM as ground water balance. The level of ground water development was

76 per cent and the state was categorized as 'grey'. But, at the districts levels there are wide variations ranging from 'white' to 'over exploited' categories (Table 5).

Out of the 5 North Gujarat districts, three, namely Mehsana, Gandhinagar and Banaskantha were falling under over exploited category while Ahemedabad and Sabarkantha were no better with the percentages development of 93 and 89, respectively. On the other hand, the utilization of ground water in the southern districts was very poor. In Surat district, which has got the maximum balance of ground water with a figure of 756 MCM/ year, is utilizing only 32 per cent of the same.

Table 5: Status of ground water exploitation in Gujarat (1997)

District	Ground water balance (MCM)	Ground water development (%)	Category
Ahemedabad	55.85	92.63	Dark
Amreli	196.92	71.03	Grey
Banaskantha	-91.45	111.49	OE
Baroda	278.99	63.90	White
Bhavnaagar	277.93	62.98	White
Bharuch	161.33	59.61	White
Bulsar	392.71	45.45	White
Dangs	71.33	1.03	White
Gandhinagar	-41.09	146.04	OE
Jamnagar	277.80	57.44	White
Junagadh	217.38	77.59	Grey
Kheda	252.48	72.80	Grey
Kutch	70.41	85.96	Grey
Panchmahal	286.64	45.85	White
Rajkot	299.46	69.57	White
Sabarkantha	86.54	88.75	Grey
Surat	755.69	32.00	White
Surendranagar	147.91	70.54	Grey
Mehsana	-557.42	164.65	OE

<70% White; 71-90 Grey; 91-100 Dark :> 100 over exploited (OE)

Source: Raman et al. (2000)

There has been a steady increase in the ground water exploitation over the years. During 1984, all districts were falling under 'white' category. Three districts during 1997 were falling under 'over exploited' category, one under 'dark' and six under 'grey'

leaving only nine districts under 'white' category. During 1984, out of the 184 talukas, 163 talukas were falling under 'white' category while the numbers reduced to 96 talukas during 1997. Simultaneously, the talukas under 'over exploited' category were only 5 during 1984 which increased to 31 during 1997 (Table 6).

Table 6: Ground water development trend in Gujarat

Category	Districts			Talukas		
	1984	**1991**	**1997**	**1984**	**1991**	**1997**
White	19	14	9	163	123	96
Grey	Nil	2	6	13	26	43
Dark	Nil	3	1	1	10	7
OE	Nil	Nil	3	5	24	31
Saline	-	-		2	31	7
Total	**19**	**19**	**19**	**184**	**184**	**184**

Source: Raman and Patil (2005)

Ground water quality

The ground water quality in the state is subjected to three major constituents. These are mainly salt concentration, nitrate and fluoride. With respect to salt concentration, waters of the eastern belt districts from the Dangs to Sabarkantha are generally good while salinity/ sodicity is observed in the waters of coastal belt of Gujarat and Saurashtra regions including Kutch and in the inland areas adjoining the coastal tract. The nitrate problem is encountered more in the districts of Amreli and Bhavanagar of Saurashtra region and the North Gujarat region contributes to the maximum of fluoride problem (Fig. 4).

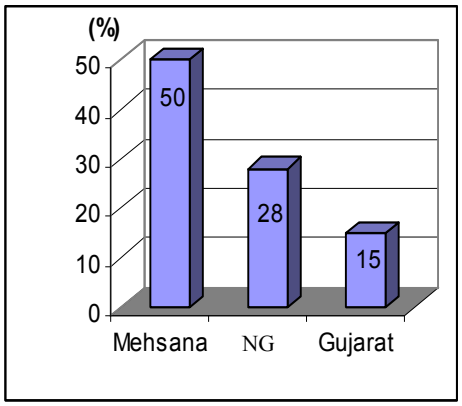


Fig. 4: Fluoride affected villages
(Source: Anon., 2004)

Per capita availability

The per capita availability of water at the state level as per the 2001 census has been reported to be 938 m^3 per year (Table 7). Falkenmark, suggested 1700 m^3 per person as the critical level for assessing the sufficiency of per capita availability. As per this standard, the state is definitely facing the acute shortage of water. Further, it striking

to note that in North Gujarat, the per cent utilization is more than 100. So there is need to take appropriate steps to minimize the per cent utilization of water.

Table 7: Per capita availability and utilization of water in Gujarat

Particulars	South and Central Gujarat	North Gujarat	Saurashtra	Kutch	Gujarat
Water availability (MCM/Yr)	37926	6105	9287	1275	**54593**
Population (million)	23.73	19.27	13.09	2.09	58.17
Per capita availability(m^3/yr)	1599	317	709	610	938
Per capita (m^3/yr) utilization	634	407	406	413	390
%utilization	40	128	57	68	42

Source: Raman and Patil (2010)

Irrigation

Out of the 196 thousand km^2 of total geographical area of the state, 124 thousand km^2 are cultivable. With all the available water resources, it is estimated that the state has an ultimate irrigation potential of 64.88 lakh ha (Table 8).

Table 8: Irrigation potential (lakh ha) in Gujarat (June, 2003)

Source	Ultimate	Potential created	Maximum utilization
A)Surface water			
Major and medium schemes	18.00	14.09	12.93
Sardar Sarovar(including conjunctive use)	17.92	0.25	0.25
Minor irrigation			
Total	3.48	2.65	1.62
	39.40	**16.99**	**14.80**
B)Ground water (including pvt. resources)	**25.48**	**20.35**	**20.33**
Total(A+B)	**64.88**	**37.34**	**35.13**
C) Rain fed Areas*	59.12	2.5	2.5
Grand Total	**124.0**	**39.84**	**37.63**

* Protective irrigation during *Kharif* with the help of water harvesting structures *etc*.

Source: Anon. (2002)

Out of the 124 lakh ha of cultivable area, the gross irrigated area in the state during 1998-99 was 38.4 lakh ha working out to a percentage of 31. The corresponding net irrigated area was 30.8 lakh hectares with a percentage of 24.8 (Fig. 5). The area

under gross canal irrigated area was 7 lakhs contributing 18 per cent of the gross irrigated area in the state. The tank command in the state is less than 1 per cent.

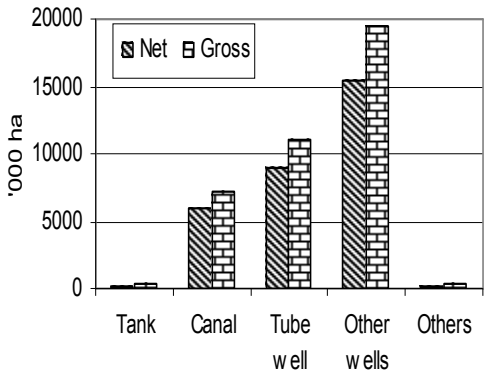


Fig. 5: **Sources wise gross and net irrigated area in Gujarat ('000 ha)**

Source : web site: Irrig .Dept.

As per the 1998-99 statistics, the state had approximately 50,000 tube wells and 8 lakh open wells. The respective intensities, as measured by the number of wells per unit area were 0.25 and 4.0. Thus, the intensity of open well in the state was 16 times more than the tube well intensity. While, the tube wells are concentrated only in North Gujarat and in parts of central Gujarat, the open wells are distributed through out the state. However, the concentrations were more in Saurashtra, followed by Central Gujarat (Table 9).

The highest intensity of tube well was observed in Gandhinagar with a value of 2.4 tube wells per km^2 followed by Surendranagar (1.64) and Mehsana (1.26).The tube wells are scanty in Saurashtra. The ill effect of high intensity of tube well in the North Gujarat, particularly in Mehsana, is reflected in the receding water table conditions and the over exploitation of ground water in Mehsana, Gandhinagar and Banaskantha districts.

Table 9: Tube well and open well intensities (No./km^2)

Taluka	Tube well intensity	Open well intensity	Taluka	Tube well intensity	Open well intensity
Ahemedabad	0.37	2.3	Kheda	0.28	3.6
Amreli	-	8.3	Kutch	-	0.6
Banaskantha	0.78	4.3	Mehsana	1.26	1.5
Bharuch	-	0.8	Panchmahals	-	7.3
Bhavanagar	-	6.7	Rajkot	-	8.0
Dangs	-	0.5	Sabarkantha	0.20	11.4
Gandhinagar	2.4	-	Surendranagar	1.64	2.8
Jamnagar	-	5.2	Vadodara	0.26	2.3
Junagadh	-	10.7	Valsad	-	3.4
			State	**0.25**	**4.0**

Source: Raman and Patil (2005)

Out of the 112 lakh ha GCA in the state, 36 lakh ha is irrigated (32%). Gandhinagar is having the highest irrigated area (73%), while Kutch and Bharuch districts have the lowest (17-19%). In North Gujarat and Saurashtra, ground water is the major source of irrigation water, while in middle and South Gujarat, surface water is predominant source. At state level, the contribution of surface and ground water is 21 and 79 per cent, respectively (Fig. 6).

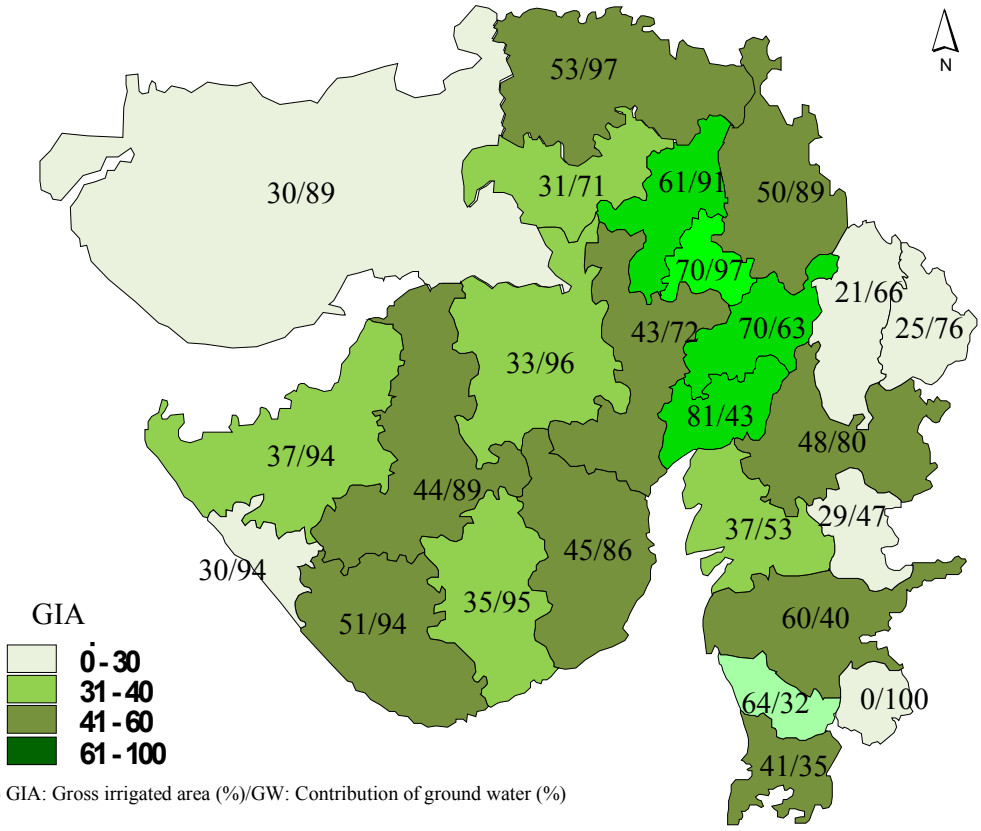
With such spatial and temporal variability in availability and quality of water in the state, the problems are bound to vary region wise. However, the major ill effects of faulty water management practice are rise in water table in canal command and receding water table in lift command.

Rise in water table: Irrigation projects play pivotal role in enhancing the crop productivity and bringing prosperity to the area. However, if the created irrigation facility is not properly utilized, then the natural resources *viz.,* soils and crops/vegetation are deteriorated to such an extent that they become unproductive. This is the case in most of the major and medium irrigation projects in different states of India and Gujarat is not an exception. In Gujarat, the ill effects like water logging, salinity and sodicity *etc.,* are apparent in both the major projects *i.e.* Ukai-Kakrapar (UKC) on river Tapi in South Gujarat and Mahi-Kadana (MKC) on river Mahi in Central Gujarat. The severity of these problems is more in South Gujarat due to higher rainfall and heavy texture of the soil than Central Gujarat (Table 10).

Table 10: Command wise water logged areas in Gujarat ('000 ha)

Command	**Water table depth (m)**	
	< 1.5	**1.5 to 3.0**
Kakrapar	11.46	66.00
Ukai Right Bank	2.15	21.00
Ukai Left Bank	2.04	13.08
Mahi Right Bank	3.94	28.80
Kadan Left Bank	0.80	5.05
Shetrunj Left Bank	0.02	5.54
Ghed	69.00	-
Total	89.41	139.56
Per cent of command	**15.00**	**39.60**

Source: Anon. (1996)



Source: Anon. (1994-95)

Fig. 6: District wise irrigated area in Gujarat

Further, the rate at which water table is rising in Surat branch of UKC suggest that about 40 per cent of the command area will become water logged with in a period of 10 years (Patel *et al*., 2000). The salinity and sodicity are the associated problems of the water logging situation. The major causes of water logging and its associated problems are due to adoption of faulty irrigation methods (flooding, field to field *etc*.) by ignoring the land irrigability classification, inclination towards high water consuming crops like paddy, sugarcane, banana *etc*., by neglecting suggested cropping pattern and heavy rainfall (1400 mm). This is also true for MKC, but with relatively less severity owing to loamy soils and relatively lower rainfall (Raman *et al*., 1999). Based on these experiences, adequate care has been taken in partly commissioned Narmada project,

wherein limited quantity of water will be supplied for low water consuming crops during r*abi* season only. Not only this, farmers are being encouraged for conjunctive use of surface and ground water.

Receding water table: Contrary to South and central Gujarat, receding water table is a matter of serious concern in North Gujarat which has arisen due to unscientific way of irrigation, higher evaporative demand and inappropriate choice of crops. As a result of this, as on today all the districts of North Gujarat (Banaskatha, Sabarkantha, Mehsana, Gandhinagar and Ahmedabad) including Kutch are in 'dark' or 'over exploited' zone. Not only this, along with receding water table @ 0.3 m/yr, ground water quality is also deteriorating at an alarming rate. Consequently, most of the ground waters are becoming unfit for irrigation and drinking as well. Though, fluoride content in ground water is above permissible limit, people are drinking such waters in absence of other options (Anon., 2004). In fact, human intervention is the cause of both rising and receding water table situations.

In order to counteract the multiplexed problems of water management in the state, the erstwhile Gujarat Agricultural University has developed crop and location specific water management technologies with the financial help from ICAR, other agencies, state government and foreign agencies and this work is being continued in all the recently formed four agricultural universities. The technologies related to surface, drip, mini sprinkler, and sprinkler irrigation along with mulching and fertigation as well as drainage are tabulated in the following chapters along with relevant success stories.

II. SURFACE IRRIGATION TECHNOLOGY

Systematic research on different aspects of water management in the state was initiated about 40 years ago with the establishment of Main Irrigation Research Centre at Navsari with 13 Trial Cum Demonstration (TCD) Farms serving as sub centres. Consequent to the handing over of TCD farms to the Government, satellite stations representing different agroclimatic conditions came into existence at Paria, Achhalia, Danti, Thasra, Sardar Krushinagar and Junagadh in addition to Narmada Irrigation Research Project at Khandha during phase-I and Thanchha, Dabhoi, Thasara and Dhandhuka during phase-II. Simultaneously, the crop specialists and professors in different campuses of the erstwhile GAU also made valuable contributions in the development of water management practices. As a result of the concerted efforts put in by all the scientists, a total of 343 recommendations were made for the farmers. The highlights of the recommendations related to surface irrigation are presented in this chapter.

A total of 162 recommendations have emerged for 48 crops grown in different agroclimatic conditions. The irrigation requirements of some of the major crops are discussed here and the details are given in table 11.

CEREALS

Paddy: The paddy crop requires a soil submergence of 5 + 2.5 cm and need to be irrigated 1-3 days after disappearance of water in the paddy areas of South and middle Gujarat. The summer paddy requires about 1100 to 1200 mm of water in South Gujarat conditions.

Wheat: The crop need as low as 6-7 irrigations under normal and four in high water table conditions in the deep Vertic Ustochrepts of South Gujarat, while it needs to be irrigated 14 times in the medium black calcareous soils of Saurashtra. Under the constraints of irrigation water, 3-4 irrigations at critical growth stages are sufficient. In typical *Bhal* conditions, wheat yield can be considerably increased by applying only one irrigation from the stored water in farm ponds.

Pearlmillet: Pearl millet grown during *kharif* needs 1-2 irrigations in the scanty and erratic rainfall conditions of Saurashtra. During summer, it requires 6-7 irrigations of 80 mm depth in the heavy soil areas and 10 irrigations of 50 mm depth in light soil areas.

Sorghum: In the heavy soil areas, the crop needs to be irrigated 2-3 times during *kharif* and 6 to 8 times during, *rabi* and summer, respectively.

PULSES

Pigeon pea: After cessation of monsoon, the crop needs to be irrigated 2-3 times at monthly interval.

Gram and wal: Though, basically they are grown on residual moisture after paddy in South Gujarat, their yields can be more than doubled, when irrigated at critical stages of branching, flowering and pod formation/grain filling stages in addition to irrigation at sowing time. The same stages were found to be effective in North Gujarat and Saurashtra conditions for gram. But in *Bhal,* it is sufficient to give only one irrigation at branching stage.

OILSEEDS

Among the major oilseed crops, castor sown in *kharif* requires about 350 to 400 mm of irrigation water which is to be supplied in 4 to 8 irrigations depending upon the texture and depth of soils. Mustard is a main *rabi* oilseed crop which needs about 3 to 5 irrigations at an interval of 3-4 weeks. Groundnut which is the predominant oilseed crop of the state, does not require any irrigation under normal rainfall conditions. But under erratic monsoonic conditions of Saurashtra, it is necessary to see that crop does not experience moisture stress condition especially at pegging and pod formation stages. On the other hand, the summer groundnut crop needs 6-9 irrigations each of 70 mm under different agroclimatic conditions not only individual crop, but irrigation schedule for groundnut + castor and groundnut + pigeon pea was also worked out.

CASH CROPS

Sugarcane: This crop has to be irrigated at 15-20 days interval during summer and 25-30 days interval during winter with a total of 13-15 irrigations. But in high water table conditions, it needs only 10 irrigations. As against this, in calcareous soils of Saurashtra it needs weekly irrigation. To reduce the irrigation water requirement, alternate furrow method of irrigation was found beneficial in the heavy textured soils of South Gujarat.

Cotton: The *kharif* sown cotton should be given 5-6 irrigations in South and middle Gujarat conditions. This can be reduced to 2 to 3 when the practice of mulching is adopted. The *rabi* sown cotton in South Gujarat heavy rainfall zone needs 9 irrigations.

Tobacco: The *bidi* tobacco grown in middle Gujarat requires 4-5 irrigations each of 50 mm depth. On the other hand, the number of irrigations should be 9 for the rustica tobacco. But in comparatively cooler winter of Vijapur this type of tobacco needs only 5-6 irrigations.

Potato: In the medium textured soils of middle Gujarat, the irrigation water requirement of this crop is around 500 mm applied in 9 irrigations.

FRUIT AND VEGETABLES

Banana: The range for the number of irrigations required for this crop is 23 to 25 in South and middle Gujarat conditions. In the latter situation, irrigating the crop by furrow method was found better than the farmers' method of flooding.

Cashew nut: Medium aged plantation (5-8 years) requires 3 irrigations. The first should be 3 months after cessation of monsoon and remaining two at bi-monthly interval.

Sapota: In the South Gujarat heavy rainfall zone, fully bearing plantation is to be irrigated at 16 to 18 days interval during winter and 10-12 days during summer amounting to total of 16 irrigations each of 60 mm depth.

Watermelon: When grown in the cultivated field condition in South Gujarat, this crop is to be irrigated 7-8 times.

Brinjal: This crop requires about 480 mm of water to be applied with a depth of 80 mm for each irrigation. After the first irrigation at transplanting and second at 15 days after transplanting, the crop needs to be irrigated at an interval of 20-27 days in South Gujarat heavy rainfall conditions. In the black soils of Narmada command of middle Gujarat, the interval should be shorter.

Chillies: The *rabi* sown chillies crop needs to be irrigated 12 times with 80 mm depth in South Gujarat heavy rainfall zone.

Onion: The available results indicated that this crop is to be given 9 irrigations in North Gujarat (Pilwai), 11 irrigations in heavy soils of South Gujarat heavy rainfall region and 14 irrigations in calcareous soils of South Saurashtra zones.

Tomato: While the hybrid (Rupali) variety requires 9 irrigations, the HYV (Pusa *Rabi*) requires 7 irrigations when grown during *rabi* season in South Gujarat heavy rainfall zone.

Others: In South Gujarat heavy rainfall as well as heavy soils of middle Gujarat zones, cabbage crop requires 6 irrigations. The summer crops of cowpea and cluster bean are required to be irrigated 10-12 times while that of *okra* 8 times in South Gujarat heavy rainfall zone.

SPICES AND CONDIMENTS

Among the different crops, cumin and fennugreek require 3-5 irrigations and fennel 7-10 depending upon the soil type. Garlic grown under South Saurashtra conditions needs 14 irrigations.

Table 11: Surface irrigation technologies

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
1.	Amaranthus (GA-1)	S.K. Nagar	NG	6 (50)	AS, 5-6 DAS, rest 20 DI	1996/25
2.	Banana (Basrai)	Navsari	SG	23	15 DI – winter 8 DI – summer	1978/8
3.	Banana (Basrai)	Navsari	SG	24 (80)	Inter cropping of turmeric found beneficial	1989/18
4.	Banana (Basrai)	Navsari	SG	24 (80)	25-30 DI Oct –Feb. 15-20 DI March – May	1992/21
5.	Brinjal	Navsari	SG	6 (80)	AS, 15 DAS , rest 22-27 DI	1993/22
6.	Brinjal	Anand	MG	15 (60)	AS, 8-10 DI Nov., 10-12 DI Dec.-Feb., 6-8 DI March	1993/22
7.	Brinjal	Khandha	MG	12 (80)	1st at TP next 3 at 10-12 DI , five at 15-17 DI & last three at 20 DI	1996/25
8.	Cabbage	Navsari	SG	6 (80)	AS, 10 DAS, rest 15 DI	1995/24
9.	Cabbage	Khandha	MG	6 (80)	AS, ,7 DAS, rest 16 DI	1996/25
10.	Cabbage	Thasra	MG	5 (60)	6 DAT & rest 15-18 DI	1999 /28
11.	Cashewnut (5-8 yrs age)	Paria	SG	3-4 (60)	1st - 3 months after the cessation of monsoon , rest 60 DI	1996/25
12.	Castor (GAUCH 1)	S K Nagar	NG	5-8	15 days after cessation of monsoon 20 DI	
13.	Castor (GAUCH 1)	Junagadh	S	5 – 8	20 DI	1989 /18
14.	Castor (GCH-4)	Khandha	MG	4 (80)	1st 40 days after cessation of monsoon & 2nd at 20-25 days after 1st one Rest 30 DI	1994/23
15.	Castor (GAUCH 1 or GCH-4)	S.K.Nagar	NG	8 (50)	15 DI Sept. - Nov., 20 DI Dec. - Feb.	1996/25
16.	Castor (R)	SKNagar	NG	14 (60)	10 DI Oct.-Nov., 15 DI Dec.-Feb.	1998/27
17.	Castor (GCH-4)	Navsari	SG	8(60)	Fist 4 at 20-25 DI Rest 4 at12-18 DI	2007/3
18.	Cauliflower	Navsari	SG	7 (60)	AS, 9, 31 DAS, Rest 18-20 DI.	1998/ 27
19.	Chickpea	Navsari	SG	4	Sowing, branching, flowering, pod formation	1979/9

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
20.	Chickpea (ICCC-4)	Junagadh	S	5(50)	AS,10-12 DAS, Rest 18-20.DI	1987 / 17
21.	Chickpea	Arnej	MG	1 (50)	At branching	1993/ 22
22.	Chickpea	Khandha	MG	-	Check basin 8x4m	1993/ 22
23.	Chickpea	Khandha	MG	2 (75)	1st- at sowing 2nd- at flowering	1995/24
24.	Chickpea	S.K. Nagar	NG	5	20 DI	1995/24
25.	Chickpea	Derol	MG	2(60)	Branching & Pod filling	2009/5
26.	Chicory	Anand	MG	11 (50)	AS, 20, 40, 60, 80, 95, 110, 120, 130, 140, 150 DAS	1997/26
27.	Chiku (Kalipatti)	Navsari	SG	10-11	32 DI – winter 18 DI – summer	1989/18
28.	Chillies	Khandha	MG	7 (80)	One month after cessation of monsoon, Rest 20-25 DI	1998/27
29.	Chillies (R)	Navsari	SG	12 (80)	AS,10,25-30 DAS, Rest 20-25 DI Jan.-Feb. 12-15 DI March-May	1996/
30.	Chillies	Achhalia	SG	4 (80)	15 days after cessation of monsoon, Rest 30 DI	1997/ 26
31.	Clusterbean (GC-1)	Anand	MG	2	Branching & Flowering	2009/5
32.	Clusterbean (GC-2)	Derol	MG	2	Branching & Flowering	2011/7
33.	Cotton	Navsari	SG	4	Alternate furrow irrigation with plastic mulch reduces IR by 50%	
34.	Cotton	Khandha	MG	5 (80)	1st irri. one month after cessation of monsoon , Rest at 18-21 DI	1994/23
35.	Cotton	Achhalia	SG	2-3	After cessation of monsoon at monthly interval	1995/24
36.	Cotton (G.Cot.Hy-8)	Surat	SG	4 (70)	20-25 days after cessation of monsoon , Rest 24-28 DI	1996/25
37.	Cotton (R)	Navsari	SG	9 (80)	AS, 7 DAS, 25 DI up to Feb. , 15 DI March- April	1996/25
38.	Cowpea (Pusa Falguni)	Navsari	SG	12	AS, 4 DAS, Rest 8-10 DI	1979/9
39.	Cowpea (Pusa Komal)	Paria	SG	9 (60)	AS, 15,30 DAS, Rest - 12 DI	1996/25

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
40.	Cumin	Navsari	SG	4	(i). 50 mm AS (ii) 50 mm 10 DAS (iii) 70 mm 37 DAS and (iv) 70 mm 59 DAS	1984/14
41.	Cumin (GC-4)	Jagudan	NG	4(50)	AS,8-10,30 &45-50 DAS	2009/5
42.	Fennel	Navsari	SG	9 (60)	AS, 20 DI Nov.-Jan. 15 DI – Feb.	1984/14
43.	Fennel (G-11)	Ladol	NG	7(60) 7(40)	1st -18-20 DI,2nd & 3rd -13 DI, 4th & 5th -15 DI, 6th & 7th- -14 DI Water scarce condition(Alternate furrow)	2010/6
44.	Fennel (GF-1)	Jagudan	NG	10 (50)	AS, 8, 33 DAS, Rest 12-15 DI	1998/27
45.	Fenugreek	S.K. Nagar	NG	7	AS, Rest 15 DI	1992/21
46.	Garlic	Junagadh	S	14 (50)	AS, 5,10 DAS, 4th to 9th - 10-12 DI, 12th to 14th - 7-8 DI	1995/24
47.	Garlic	Navsari	SG	11(60)	AS,2nd 9-10 DI, Rest-9-15 DI	2012/8
48.	Gram (Gujarat-2)	Tanchha	SG	1(60)	Sowing or Branching (60 % more yield than conserved moisture)	2006/2
49.	Green gram (Su)	Navsari	SG	5 (80)	AS, 7 DAS, Rest 15-16 DI	1989/ 18
50.	Green gram (Su)	Navsari	SG	5 (80)	AS, 7 DAS, Rest 16-17 DI	1989/18
51.	Green gram (Su)	Navsari	SG	5 (80)	AS, 7 DAS, Rest 16-17 DI	1989/18
52.	Green gram (Su)	SKNagar	NG	7 (60)	First 3 at 9 DI, Rest 7 DI	1997/ 16
53.	Groundnut	Junagadh	S	1 to 3	As and when needed.	1982/12
54.	Groundnut	Targhadia	S	1 (50)	Light irrigation during dry spell	1983 / 13
55.	Groundnut (S) (GAUG	Junagadh	S	14	7-8 DI	1983 / 13
56.	Groundnut (GAUG-1)	Junagadh	S	12 (50)	AS,8DAS, 3rd-5th 12DI, Rest 8-10 DI	1985 / 15
57.	Groundnut (Su)	Navsari	SG	7 (80)	AS, 7 DAS, Rest 13-15 DI	1985/15

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
58.	Groundnut (Su)	Navsari	SG	-	1.5 lps/m width furrow irrigation	1986/16
59.	Groundnut (Su)	Navsari	SG	8	AS, 8 DAS, branching, flowering, pod formation, pod penetration, pod Filling and pod development	1987/17
60.	Groundnut (Su)	Anand	MG	9 (50)	AS,25-30,40-45,55-60,80-85,91-95,102-107 and 115-120 DAS	1993/ 22
61.	G'nut (Su)	Thasra	MG	8 (60)	15 DI, March, 7-8 DI April-May	1995/24
62.	Groundnut (GG-7) + Castor(GCH -6) 3:1 row ratio	Junagadh	S	4	AS, 2ed -20 DAS, Rest-20DI	2008/4
63.	Groundnut (GG-20) + Pigeon pea (Vaisali) 2:1 row ratio	Junagadh	S	4	10 DI	2008/4
64.	Indian bean	Navsari	SG	4	AS, branching, flowering, pod formation	1979/9
65.	Indian bean (Kadva Val-125-36)	Navsari	SG	5	PS, branching, flowering, pod formation and grain filling stages	1990/19
66.	Isabgul (G-1)	Junagadh	S	10 (50)	AS, 60 DAS, Rest 12-15 DI	1991/20
67.	Lucene	Khandha	MG	11 (80)	AS, 7 DAS, Dec. - Feb.- 18 DI, Rest- 10-12 DI	1994/23
68.	Lucerne	Khandha	MG	-	Basin size 4x8m Flow rate 6 LPS	1994/23
69.	Lucerne (Anand-2)	Navsari	SG	18	10 DI in winter 8 DI in summer	1996/25
70.	Maize	Navsari	SG	11 (70)	9 DI	1981/11
71.	Mango (local)	Paria	SG	3	Pea, Marble & 20 day after marble stage	2011/7
72.	Maize (R)	Thasra	MG	6-7 (60)	15-18 DI up to Feb., 10-12 DI March	1998/ 27
73.	Maize (R)	Godhra	MG	11	AS, 20 DAS, 3rd - 9th =10-12 DI Rest 7 DI,	1998/ 27
74.	Maize (GM-3)	Godhra	MG	7(60)	AS, 2rd _6 DAS, 3th- -30 DAS, rest 4 at 15-20 DI	2007/3

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
75.	Mustard (T59)	Navsari	SG	4 (60)	AS, 28, 54, 75 DAS	1989/28
76.	Mustard	Navsari	SG	4-5 (60)	20-22 DI	1990/
77.	Mustard	Arnej	MG	1 (50)	At 30 DAS for normal monsoon year	1993/ 22
78.	Mustard (GM-1)	Anand	MG	3 (50)	25-30,45-50, 75-80 DAS	1994/23
79.	Mustard	Arnej	MG	1 (50)	Branching	1997/ 26
80.	Mustard	SKNagar	NG	5 (50)	PS, 15, 45, 60, 70 DAS,	1998/27
81.	Mustard (Varuna)	Khandha	MG	4 (80, 60)	30 DI	1999/28
82.	Mustard (GM-1)	Khandha	MG	4 (60)	I-S, II-Br, III- SL, IV- GF	99-01/38$
83.	Nizer (R) (RCR-317)	Navsari	SG	4(60)	AS, 2nd 18-20 DI, Rest-24-25 DI	2008/4
84.	Oil palm (Hybrid)	Paria	SG	18 (60)	20 DI: Winter, 11 DI: Summer	95-99/36$
85.	Okra (Su)	Navsari	SG	13 (60)	AS, 7,14 DAS, Rest 9-10 DI	1994/23
86.	Okra (Su)	Paria	SG	8 (60)	AS, 15,30 DAS, Rest 10 DI	1996/25
87.	Okra (Su) (Parbhani Kranti)	Thasra	MG	9 (60)	8-9 DI	97-99/36$
88.	Onion	Navsari	SG	11 (60)	AS, 7 DAS, Rest 10-11 DI	1990/19
89.	Onion	Junagadh	S	14 (50)	AS, 5,10 DAS, 3rd and 4th 8-10 DI, Rest 6-7 DI	1995/24
90.	Paddy	Navsari	SG	-	Puddling by tractor with cage wheel reduces percolation losses	1983/13
91.	Paddy	Navsari	SG	-	5.0 – 7.5 cm to saturation	1989/ 18
92.	Paddy	Danti	SG	-	5.0 cm to saturation	1989/ 18
93.	Paddy	Thasra	MG	-	5-7.5 cm two days after disappearance	1993/ 22
94.	Paddy (Summer)	Navsari	SG	-	5.0 cm two days after disappearance	1993/ 22
95.	Paddy (Summer) (Gurjari)	Navsari	SG	-	3-5 days after disappearance of water(puddling by power tiller)	2008/4
96.	Palmarosa (RC-1)	Navsari	SG	14(60)	25-27 DI Oct-Nov 12-14 DI Mar-Jun	2008/4
97.	Pearl millet (Summer)	Thasra	MG	5-6 (60)	AS, 13-15 DI up to March 10-12 DI April	1998/ 27
98.	Pearl millet (Summer) (GHB-30)	Anand	MG	10 (50)	10 DAS, Rest 7 DI	1990/ 21

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
99.	Pearl millet (Summer)	Kholwad (TCD)	SG	7	First after sowing , Rest 12 DI	1979/9
100.	Pearl millet (Summer)	Chikhali (TCD)	SG	6	First after sowing, Rest(s) 15 DI	1979 / 9
101.	Pearl millet (GHB-558)	Junagadh	Sau	13(40)	6-7 DI	2006/2
102.	Pigeon pea (T-15-15)	Navsari	SG	2 (80)	34-40 DI	1984/14
103.	Pigeonpea	Achhalia	SG	2-3 (70)	Monthly interval after cessation of monsoon	1995/24
104.	Pigeonpea (BDN-2)	Khandha	MG	3 (80)	Monthly interval after cessation of monsoon	1996/25
105.	Pigeonpea (BDN-2)	S.K.Nagar	NG	3 (60)	15-17 DI after cessation of monsoon	1996/25
106.	Pigeonpea (R) (BDN-2 or GT-100)	Khandha	MG	6 (80)	AS, 30, 60, 90, 120, 140 DAS	1998/ 27
107.	Pigeonpea ® (BDN-2)	Navsari	SG	3	AS, Rest 60 DI	1995/24
108.	Pigeonpea (semi rabi)	Vadodara	MG	2(60)	Branching & pod development stage	2009/5
109.	Potato	Anand	MG	9 (50)	PS, emergence, Rest 8 DI	1993/ 22
110.	Rajgira	Thasara	MG	5(50)	20-30 DI	2011/7
111.	Safflower	Navsari	SG	6 (60)	AS, 15 DAS, Rest 21-28 DI	1995/24
112.	Safflower	Anand	MG	2 (50)	Sowing, seed development stage	1998/ 27
113.	Sapota (Kallipatti)	Paria	SG	-	16 DI Winter 10 DI Summer	2011/7
114.	Sesamum (Gujarat-1)	Navsari	SG	5 (60)	AS, 7 DAS, Rest 22 DI	1985/15
115.	Sesamum (S) (GT-1)	Navsari	SG	8 (60)	AS, 7 , 14 DAS, Rest 10-14 DI	1995/24
116.	Spider lily (Local)	Navsari	SG	20(60)	13-15 DI Winter 7-10 DI Summer	2011/7
117.	Sorghum (Ratoon CSH-5)	Navsari	SG	7	1st at harvest, 2nd at 7th DI, rest 11-13 DI	1983/13
118.	Sorghum (Ratoon CSH-5)	Navsari	SG	7	1st at harvest of the crop 2nd at 4-5 LS, 3rd at knee high stage 4th at FL, 5th at F, 6th at GF and 7th dough stage	1983/13

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
119.	Sorghum (Ratoon CSH-5)	Navsari	SG	4 (Under limited available water)	1st at harvest, 2nd at the knee height, 3rd at BL, 4th at GF	1983/13
120.	Sorghum (Su)	Navsari	SG	8 (60)	AS, 7 DAS, rest 13-15 DI	1984/14
121.	Sorghum	Navsari	SG	-	The var. CSH-5 showed tolerance against waterlogged conditions	1992/21
122.	Sorghum (GJ-37)	Khandha	MG	3 (80)	Knee height, flag leaf, flowering	1999/ 28
123.	Sorghum(R) (BP-53 or GJ-38)	Navsari	SG	6(60)	AS, 2nd 8-10 DI, Rest-20-24 DI	2008/4
124.	Sugarcane	Navsari	SG	15 (80)	21-24 DI – Winter 13-15 DI- Summer	1981/11
125.	Sugarcane	Navsari	SG	20 (60)	Alternate furrow irrigation can save 43 % irrigation water	1987/17
126.	Sugarcane	Junagadh	S	46 (30) 34	5-6 DI summer 7-8 DI 8-10 DI using s'cane trash as mulch	1991/ 20
127.	Sugarcane	Navsari	SG	-	Spent wash-50 times dilution with canal water	1994/23
128.	Sugarcane	Navsari	SG	-	Water table need to be maintained below 1.5 m to avoid 20-30% loss in yield and to control development of soil salinity	1994/23
129.	Sugarcane	Khandha	MG	16 (80)	18-20 DI up to Feb., 11-14 DI March-April, 9-10 DI May-June	1997/ 26
130.	Sugarcane (CO-419)	Navsari	SG	14	20-22 DI – *Rabi* 15-16 DI – Summer	1978/8
131.	Sugarcane (CO-419)	Navsari	SG	13	25-30 DI winter 15-20 DI summer	1979/9
132.	Sugarcane (High water table)	Navsari	SG	10 (60)	-	1991/20
133.	Sugarcane (CO-07527)	Thasra	MG	14 (80)	20-22 DI: Dec.-Feb, 11-13 DI: March, 8-10 DI: onward	97-99/37
134.	Sunflower (Su)	Navsari	SG	9 (60)	AS, 11 DAS, Rest 8 DI	1997/ 26

135.	Tobacco (GC-1)	Anand	MG	9 (50)	15, 30, 45 DAS, Rest 10 DI	1990/ 19
136.	Tobacco (GT-5)	Anand	MG	4-5 (60)	After cessation of monsoon 12 – 15 DI	1990/ 19
137.	Tobacco (A 119)	Anand	MG	4 (60)	20-25 DI	1990/ 19
138.	Tobacco (Culcutti-1)	Anand	MG	5-6 (60)	25 DAS, 18-20 DI	1992/ 21
139.	Tobacco	Anand	MG	3-4 (50)	After cessation of monsoon at 25 - 30 DI	1993/ 22
140.	Tobacco (GT-7)	Anand	MG	2 (50)	60, 100 DAS	1997/ 26
141.	Rustica Tobacco (GCT-3)	Dharmaj	MG	9(50)	First 3 at 15 DI Rest 6 at 10 DI	2011/7
142.	Tomato (Rupali)	Navsari	SG	9-10 (80)	15-20 DI, Sept-Oct. 20-25 DI, Nov.	1991/20
143.	Tomato (Pusa Rubi)	Navsari	SG	7 (80)	AS,2nd- 4th days after planting, rest at 15-20 DI	1994/23
144.	Water melon	Paria	SG	7-8 (60)	AS, 30 DAS rest 15 DI	1994/23
145.	Wheat (Lok-1)	Khandha	MG	4 (80)	AS, CRI, tillering, panicle initiation or flowering or milky stage	
146.	Wheat (J-24)	Navsari	SG	6	AS, 7 DAS, rest 20 DI	1979/9
147.	Wheat	Arnej	MG	1 (50)	Rain harvested water at CRI/tillering	1984 / 14
148.	Wheat (Lok –1)	Junagadh	S	10 (50)	PS,6 DAS, rest 8-10 DI	1985 / 15
149.	Wheat (Lok-1)	Navsari	SG	7 (60)	AS, CRI, Rest 12-13 DI	1986/16
150.	Wheat	Vijapur	NG	7 (60)	21, 34, 45, 56, 67, 78, 91 DI	1989/18
151.	Wheat (Lok-1)	Achhalia	SG	7 (70)	AS, 8 DAS, rest 14-15 DI	1992/21
152.	Wheat	Khandha	MG	7 (80)	AS, 19-20 DAS, Rest 12-13 DI	1992/ 21
153.	Wheat (Lok-1)	Vijapur	NG	7 (60)	AS,15 DAS, rest 12 DI	1993/ 22
154.	Wheat (Lok-1)	Thasra	MG	5-6 (60)	AS, 18-22 DAS, rest 15-20 DI	1994/23
155.	Wheat	Anand	MG	5-6 (60)	AS, 18-22 DAS, rest 15-20 DI	1995/24
156.	Wheat	Navsari	SG	5-6 (60)	AS, Rest 20 DI	1997/ 26

SN	Crop (Variety)	Location	Region	No. irri. (D: mm)	Schedule	Year/ JA. No.
1	2	4	3	5	6	7
157.	Wheat (GW-173)	Vijapur	NG	5 (50)	PS, 18, 35 DAS, rest 10-12 DI	1997/26
158.	Wheat (Lok-1)	Navsari	SG	8 (60)	AS, 15, 30, 45, 57, 69, 79, 89 DAS	1999/ 28
159.	Wheat (Lok-1)	Danti	SG	5 (60)	AS, 21, 42, 63, 80 DAS	1999/28
160.	Wheat (GW 173/ GW 275)	Danti	SG	4 (60)	AS, CRI, Tiller, Boot leaf	2004/40 $
161.	Wheat (GW-322)	Junagadh	S	7	At sowing, CRI, tillering, boot, flowring, milky & dough stages	2008/4
162.	Wheat (GW-496)	Dabhoi	MG	5(60)	At sowing,CRI, tillering, flowering and grain filling	2008/4

Abbreviations used:

$	Agron. & Soil Sci. Sub Committee No.	m	metre
AS	After sowing	MG	Middle Gujarat
ASM	Available soil moisture	mm	milli metre
D	Depth of irrigation in mm	NG	North Gujarat
DAS	Days after sowing	PS	Pre sowing
DAT	Days after transplanting	R	*Rabi*
DI	Days interval	S	Saurashtra
IR	Irrigation requirement	SG	South Gujarat
JA	Joint AGRESCO No.	Lps	Liter per second

Success story: Land Configuration + Organics

After developing water management technologies, these technologies reached to the farmers through DoA, DoH, NGOs, KVK *etc.* The water management technology with special reference to raised bed planting was demonstrated on farmers' field such 58 demonstrations each of 1 ha area. The impact of raised bed planting on productivity of *rabi*/summer crops was assessed. The farmers feed back and their opinion is narrated here as a success story.

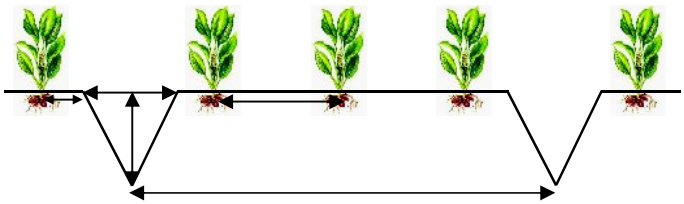
In South Gujarat, irrigated as well as rainfed transplanted paddy is grown in about 2.5 lakh ha area. The soils under this crop are clay in texture. Because of puddling in *kharif* (monsoon) paddy, the physical properties of high clay containing soils are deteriorated. These deteriorated physical properties impair the water and air movement in the soils and there by adversely affecting the productivity of *rabi/*summer crops grown after *kharif* paddy. For improving the productivity of *rabi*/summer crops under such situations, an appropriate land configuration coupled with use of organics technology (LC) has been perfected for different crops in AICRP on WM, Navsari Agricultural University, Navsari Centre (Gujarat). Subsequently, this technology was taken to the farmers' fields through some ToT projects especially FPARP.

In order to popularize this technology among the paddy growers of South Gujarat, large scale demonstrations (1 ha each) covering 23 villages spread over four districts of South Gujarat *viz.*, Bharuch, Surat, Navsari and Valsad. The district wise villages and taluka covered are reported in table 12.

Table 12: Details of districtwise demonstration on land configuration + Organics

SN	District	Taluka	No of villages	No. of demonstration	Area (ha)
1	Surat	Kamrej	3	13	10.50
		Olpad	1	6	6.00
2	Navsari	Jalalpor	3	9	5.40
		Chikhali	3	5	2.28
3	Valsad	Valsad	6	11	4.68
4	Bharuch	Valiya	2	6	6.00
		Jhagadiya	2	2	1.00
		Hansot	3	6	4.14
Total			**23**	**58**	**40.00**

The results of demonstrations covering seven crops reported in table 13 clearly indicate that irrespective of crops, the yield increase was ranging from 10 per cent with cabbage to 19 per cent with cauliflower. Similarly, the water use efficiency values were also higher with land configuration practice as compared to farmer's method. This implies that with less amount of water higher biomass yield can be obtained. Apart from yield advantage, land configuration technology also gives more net profit than conventional practice. *i.e.,* it is techno economically vial technology.



Schematics of raised bed

Table 13: Yield, WUE, water saving and increase in yield over conventional method

SN	Crop	No of demonstration	Yield (t/ha)		Water saving (%)	% increase in yield over CP	WUE (kg ha-mm)	
			C P	LC			C P	LC
1	Onion	19	16.3	18.6	36.0	17.0	30.1	51.0
2	Brinjal	2	19.7	23.6	33.0	17.0	32.8	54.5
3	Cauliflower	8	15.8	18.9	41.0	19.0	34.8	55.5
4	Wheat	20	5.9	6.9	30.0	15.0	10.1	16.8
5	Sorghum(*rabi*)	1	2.6	3.0	38.0	15.4	7.2	115.0
6	Castor(*rabi*)	7	1.6	1.9	31.0	16.0	7.9	9.5
7	Cabbage	1	13.8	15.2	29.0	9.73	32.9	50.5
	Total	**58**						

CP : *conventional practices,* ***LC:*** *land configuration + Organics*

While monitoring the demonstrations, the farmers' feed backs were collected. They opined that adoption of land configuration technology facilitated uniform as well as better germination, enabled to save water as well as time required for irrigation and ease in harvesting of crop particularly onion. They further observed that application of organic manures along with gypsum (soil test based) resulted in early *vapsa* condition thereby enabling to do timely interculturing which control weed effectively. Some of the

farmers observed improvement in quality of produce along with early maturity. Because of these advantages, farmers were able to bring their produce early in the market and realized higher price.

The economics computed for different crops under land configuration (Table 14) shows that if farmers who have adopted this technology in *rabi*/summer crops could realize higher net profit (Rs.29895 to 94000/ha), then they need not to go for summer paddy (net profit: 15000-2000 t/ha) which require about 1500 mm water.

In view of the advantage associated with LC technology and excellent response of the farmers, Navsari Centre is striving for bringing more area under land configuration + organics through *Farmers day*, *Krishimahotsav* and literature publications. For this purpose, Sugar co-operative, NGO and DoA are also actively participating in the activities.

Table 14: Economics of land configuration in different crop

SN	Crop	Yield (t/ha)	Selling price(Rs/ kg)	Cost of cultivation (Rs/ha)	Gross realizati on (Rs/ha)	Net income (Rs/ha)
1	Brinjal	23.60	5.00	23700	118000	94000
2	Castor	1.90	25.00	15700	47500	31800
3	Onion	18.60	5.00	20500	93000	72500
4	Cauliflower	18.90	5.00	16900	94500	77600
5	Cabbage	15.20	5.00	16900	84500	67600
6	Sorghum(*rabi*)	3.00	15.00	15105	45000	29895
7	Wheat	6.90	13.00	13442	89700	76258

Epilogue:

Adoption of land configuration technology will not only benefit the terms of yield and monitory return, but will also encourage the farmers to grow crops other than summer paddy. This ultimately will help in mitigating the twine problems of water logging and secondary salinization which are serious concerns in Ukai-Kakarapar Command.

III. DRIP TECHNOLOGY

Considering the importance of research in water saving method, the university has launched systematic research on sprinkler, drip and mini/micro sprinkler since 1989. Utilizing the infrastructural facilities available at four main campuses and 56 off campus research stations, collaborative research work is being conducted to develop agroclimatic zonewise appropriate technologies on modern methods of irrigations. The recommendations made based on the concluded experiment are summarized here.

So far 108 technologies have been developed on drip alone, drip + mulch and fertigation for 35 different crops grown in four agroclimatic zones (Tables 15). It is seen that for most of the crops, the water saving over recommended surface method is 40 to 50 per cent. The yield increase per hectare varied from 3 to 60 per cent depending upon type of drip technology. Similarly, the net return per hectare mm water used varies from Rs.2 to 728.

Table 15: Drip technologies

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
1	Banana /Basarai (180 x 180) Drip Drip + BPM Drip + STM	Navsari	SG	 30 43 43	 7 8 17	 33 28 47	180	30 cm away from stem	4 (2)	90 min. - Jan-March 120 min. - April-June 68 min. - Oct-Dec.	88-89/28
2	Banana/ Basarai (100 x 120 x 200)	Navsari	SG	40	28	38	320	100	8	150-180 min. - winter 210-270 min. - summer	94-97/35
3	Banana/ Basarai (150 x 150)	Navsari	SG	38	3	NA	150	30 cm away from stem	4 (2)	90-120min. - winter 150-165min. - summer (7 equal split at 20 DI, 40% NPK saving)	94-95/33
4	Banana/ Basarai (150 x 150) Drip + BPM Drip + STM	Navsari	SG	 30 30	 50 60	 94 104	150	30 cm away from stem	4 (2)	90-120min. - winter 150-165min.- summer (60-90 % weed control)	91-93/30
5	Banana/ Basarai (180 x 180) (Drip + STM)	Navsari	SG	30	-	60	180	30 cm away from stem	4 (2)	90-120min.- winter 150-165min.- summer (60 % N saving)	91-93/30
6	Banana/ Basrai (150 x 150)	Paria	SG	46	26	306	150	150	4 (2)	90 min. Winter, 105 min. Summer	98-00/37
7	Banana/ Basrai (150 x 150)	Achhalia	SG	48	14	82	150	150 30 cm away from stem)	4 (2)	60 min. Oct. – Jan. 110 min. Feb. –March 180 min. Onward	98-00/37
8	Banana/Grand nine (240 x120)	Navsari	SG	-	-	-	240	60	4	80 % RDF + three liters of banana pseudostem sap per plant (10 equal splits of sap at 10 DI , starting from 60 DAP)	2011/7

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
9	Banana/Grand nine (180 x180)	Gandevi	SG	-	-	1:3.07	180	30 (both side)	4(2)	140-150 min Jul-Nov (except rainy day) 140-150 min Dec-April 180-190 min May 235-245 min June (25 % N saving)	2011/7
10	Ber / Gola (650 x 650)	S.K. Nagar	NG	12	17	109	650	50-100 cm away from trunk	4 (10)	105 min.	93-99/36
11	Ber/ Gola (650)	S.K. Nagar	NG	12	17	109	650	50-100 cm away from trunk	4 (10)	60-105 min.	93-99/36
12	Bitter gourd/ Hy. Namdhari (50 x 50 x 150)	Navsari	SG	40	18	221	200	100	8	100 min.	00-01/38
13	Brinjal (60 x 60 x 120)	Anand	MG	24	18	NA	180	120	2	330 min. - Nov 290 min.- Dec-Feb. 405 min. - March 520 min. - April	91-92/29
14	Brinjal /Surati ravaiya	Navsari	SG	-	-	1:6.3	180	60 MT	-	AD/ Low energy drip	02-03/40
15	Brinjal/ Surti Ravaiya (50 x 75 x 100)	Danti	SG	37	17	207	150	75	4	45- 75 min. Winter, 75-105 min. Summer < 6 dS/ saline water used	99-00/37
16	Brinjal/ Surti Ravaiya (50 x 75 x 100)	Navsari	SG	-	21	134	150	75	4	75-90 min. Winter, 90-120 min. Summer Saline water up to 4 dS/m + Mulching	99-00/37

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
17	Brinjal/ Surti ravaiya (75 x 60) (Drip + BPM)	Khandha	MG	40	35	NA	75	120	3	150 min. - Oct. - Jan. 220 min. - Feb-March	94-96/32
18	Brinjal/BSR-1 (50x75x100)	S.K. Nagar	NG	8	19	50.2	150	75	4	180 min.- Sept.- Oct. 140 min.- Nov.- Feb. 220 min. – till harvest	01-03/40
19	Brinjal/ Surti ravaiya (60 x 60x120) + BPM(25µ ,45 % coverage)	Navsari	SG	40	40	193	180	100	8	90 min Nov-Jan 150 min Feb-March 180 min April-June	2008/4
20	Brinjal/ Surti ravaiya (60 x 60x120) + BPM(25µ ,50 % coverage) or STM, + Saline water (4 ds/m)	Navsari	SG	-	17	1:2.85	180	120	8	-Irrigation with saline water started after 30-45 DAP -After brinjal, growing *kharif* paddy for minimizing deleterious effects of accumulated salt	2009/5
21	Bottle gourd/Pussa naveen (40x100x260)+ Castor shell mulch @ 5 t/ha	S.K. Nagar	NG	27	40-50	59	300	100	8	35 min. - Feb. 50-65 min.-Mar-April 70 min. –May-harvest	2008/4
22	Cabbage/ Golden acre (30 x 30 x 60)	Navsari	SG	34	46	NA	90	60	4	60 to 75 min. (20 % N saving)	93-95/32
23	Cabbage/ Golden acre (30 x 60)	S K Nagar	NG	45	34	200	90	60	8	50 min Oct 35 min Nov-Jan 50 min till harvest (25 % basal and 75 % N in three equal splits at 15 DI, 20 % N saving)	2009/5

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
24	Cabbage/ Golden acre (45 x 45 x 60)	Anand	MG	40	17	510	120	45	4	40-50 min (5 equal splits at 10 DI, starting from 15 DAS, 20 % NPK saving)	2011/7
25	Castor/ GCH-4	Khandha	MG	73	31	97	-	90	3	25-30 min.-Oct.-Jan	93-96/33
26	Castor/ GCH-4 (90 x 60)	S.K. Nagar	NG	25	36	25	90	60	4	40 min- Sept.-Nov. 30 min - Dec.-Feb.	91-94/32
27	Castor/ GCH-4 (45 x 60 x 135)	S.K. Nagar	NG	-	3	46.4	180	60	8	125 min. Oct., 150 min.- Nov and Feb., 80 min.- Dec- Jan, 60 min. March, 200 min. till harvest	01-03/40
28	Castor/ GCH-4 (60 x 60 x 120)	S.K. Nagar	NG	NA	21	NA	180	60	8	40 min- Sept.-Nov. 30 min - Dec.-Feb.	96-98/35
29	Castor/GCH-4 (60 x 60 x 120)	Navsari	SG	38	32	153	180	120	8	50 min. up to Jan. 60 min. up to Feb. 75 min. during March (60% N saving)	97-98/35
30	Castor/GCH-4 (60 x 60 x 120)	Navsari	SG	39	-	52	180	120	8	40-60 min. Nov-Jan. 60-100min.Feb-harvest. (20 % basal &80% N in three equal spits at 30 DI, 30-35 % N saving)	2007/3
31	Castor/GCH-4 (60 x 60 x 120)+ Paddy straw mulch(10 t\ha) or BPM(50 µ)	Thasra	MG	-	20	81	240	60	4	420 min at 6 DI	2010/6

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
32	Castor/GCH-4 (60 x 60 x 120)+ BPM(50 μ,56% coverage)	Achhalia	SG	39	71	44	180	120	8	40-60 min Nov-Jan 60-100 min Feb-harvest (40 % N saving)	2009/5
33	Castor/GCH-5 (60 x 60 x 180)+ Paddy straw mulch(5 t\ha)	Anand	MG	31	10-12	1:4.27	240	60	4	110-130 min	2011/7
34	Castor/GCH-4 (60 x 60 x 120)	Navsari	SG	18	-	196	180	120	8	Water stress (20 day or 30 day + BPM, starting from 50 % emergence of main spike stage)	2012/8
35	Castor/GCH-5 (60 x 60 x 180)	Thasara	MG	20-25	-	1:5.52	240	60	4	120-130 min (30 basal and 70 % RDN in 4 equal splits at 30 DI)	2012/8
36	Cauliflower (Paired row)	Navsari	SG	44	20	73	90	50	4	120 min. at 3 DI	-
37	Cauliflower/ Early Snow	S.K. Nagar	NG	43	-	43	90	50	4	40 min. Nov.- Jan, 50 min. onward	98-00/37
38	Cauliflower/Pausha Himyug (30x30x60)	Ladol	NG	10	6-7	286	90	60	4	100 min Nov 70 min Dec-Jan 90 min Feb- harvest (3 equal splits of 75 % RDNK at 20,30 and 40 DAS)	2012/8
39	Chillies / Jwala (45 x45 x 75 x75)	Anand	MG	10	47	70	120	120	4	90 min Drip + BPM	95-96/36
40	Chillies/ Surya Rekha	Navsari	SG	48	16	2	120	120	8	20% Fertilizer saving	99-00/37

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
41	Chillies/ Suryarekha (Drip + 50%Green plastic) (45 x 60 x 75)	Navsari	SG	34	59	49	120	60	4	40 to 50 min.-Nov.-Feb. 60 - 75 min.- March – June, MT	93-95/32
42	Chillies/ Suryarekha (45 x 60 x 75)	Navsari	SG	41	23	59	120	60	-	40 to 50 min.-Nov.-Feb. 60 - 75 min.- March – June, MT	93-95/32
43	Chillies/GC-2 (90x60)	Jagudan	NG	15	60-65	73	90	60	4	30-40 min September 75-95 min Oct-Nov 55-60 min Dec-Jan 70-75 min upto harvest (20 basal and 80 % N in four equal splits at 30 DI)	2009/5
44	Cluster bean (S)/ Pusa Navbahar	Navsari	SG	33	50	57	120	60	2	180-210 min.	97-99/36
45	Cotton / G. Cot.-8 (60 x 60 x 180) BPM GM	Danti	SG	-	- 62 46	-	240	120	4	AD	98-00/38
46	Cotton/ G. Cot. Hy.-10 (45 x 120)	Khandha	MG	43	20	NA	120	45	4	135 min. - Nov. - Dec. 75 min. - Jan. onward. (10 equal split at weekly interval)	97-98/35
47	Cotton/ G. Cot. Hy.-6 (45 x 120)	Surat	SG	49	-	102	120	45	4	65-70 min. Nov- Feb	94-97/35
48	Cotton/ G. Cot. Hy.-8	Khandha	MG	37	33	117	120	90	4	135 min. - Nov. - Dec. 75 min. - Jan. onward.	93-95/31

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
49	Cotton/ G. Cot. Hy.-8 (90 x 45)	Navsari	SG	47	5	7	135	45	4	40-50 min. Oct.-Jan., 60-75 min. Feb.-May (25 % N saving)	93-94/31
50	Bt Cotton/ RCH-2 BG-II (60 x 45x180)	Surat	SG	20	11	169	240	45	4	70-85 min (6 equal splits of 75 % RDN at 15 DI, Starting from 15 DAS, 25 % N saving)	2012/8
51	Bt Cotton/ RCH-2 (60 x 120)	Thasara	MG	26	30-32	79	120	60	8	100 min June 60-75 min July- Oct 40-60 min Nov- Feb 95 min March up to harvest (3 equal splits of 75 % RDN at 30,60 and 90 DAS, 2 equal splits of 50 % RDP at 30 and 60 DAS, 25 % fertilizer Saving)	2012/8
52	Fennel/ GF-1 (50 x 50 x 100)	S.K. nagar	NG	51	9	41	150	20	4	90 min. Oct.- Dec. , 120 min. Jan – Feb	96-98/36

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
53	Fennel/ GF-2 (90 x 60)	Jagudan	NG	8-10	30	168	90	60	4	30-35 min September 60-75 min Oct-Nov 40-50 min Dec-Jan 50-55 min up to harvest (20 basal and 80 % N in four equal splits at 30 DI)	2009/5
54	Gladious/Psittacinus hybrid (20x20x60)	Navsari	SG	24	-	1:3.17	120	60	3	80-100 min Nov-Jan 125-145 min Feb-March (10 equal splits of NK at 7 DI, starting from 30 DAP)	200/7
55	Ground nut/ GG-2 (Micro tube)	S.K. Nagar	NG	32	-	-	60	50	MT	Under extreme water scarcity, 65 min. Feb- March, 90 min. April- May	98-00/37
56	Groundnut (s)/ GG-2 (30)	Junagadh	S	18	31	32	60	45	4	60 min	94-96/33
57	Groundnut (s)/ GG-2 (30)	Navsari	SG	30	-	NA	120	60	-	30-45 min. under normal water and 15-20 min. under constraints of irrigation water	92-93/31
58	Groundnut(s)/ GG-2 (30)	Navsari	SG	20	23	48	120	50	MT	30-45 min. under normal water and 15-20 min. under constraints of irrigation water	94-96/33

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
59	Guava/ L-49 (6 x 6)	Dehgam	NG	53	-	-	600	600	-	-	95-98/36
60	Kagzilime (600 x 600)	Anand	MG	64	-	6 Rs/lit	600	1 m away from trunk	4(4)	120 min. - Jan 300 min. - April - June 120 to 180 min - Feb. 240 min. - March onward, 120 mim. During dry spell in monsoon	90-95/32
61	Little gourd/local (250x250)	Navsari	SG	32	25-30	167	250	250	4	150-250 min Mar- Apr 110-160 min Oct-Dec	2007/3
62	Mango/ Alphanso (1000 x 1000)	Paria	SG	12-31	203	10	1000	1 m away from trunk	4 (4)	AD	92-93/30
63	Mango/ Rajapuri (800 x 800)	S.K. Nagar	NG	21	9	-	800	30-60 cm away from trunk	8 (2-5)	Vary with age and no. of dripper	95-03 / 40
64	Maize/sweet corn Var. Madhuri (45x20)+STM@6 t/ha	Thasara	MG	25	20-23	410	90	60	4	120 min	2010/6

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
65	Maize/sweet corn Var. sugar-75 (60x20)	Navsari	SG	-	65	-	120	100	8	50 min Dec-Jan 65 min Feb- March (5 equal splits of NK at 10 DI, starting from 30 DAS)	2010/6
66	Okra (S)/ GOH-1 (30 x 30 x 90)	Paria	SG	49	12	215	120	60	4	26 min. Drip + Mulch	99-00/37
67	Okra / Parbhani Kranti (30 x 25 x 60)	S.K. Nagar	NG	45	-	-	90	60	4	70 min. Feb.- March, 85 min. April- May	99-00/37
68	Okra/ Daftari-2 (30 x 30 x 60)	Navsari	SG	52	6	177	90	60	4	25 to 30 min (20% N saving)	93-95/32
69	Okra/Guj okra (60x30)	Junagadh	Sau	-	26	67	60	60	4	100-110 min	2009/5
70	Oilpalm (90x900x900, triangular)	Navsari	SG	-	-	13	900 (I-y)	50	8(2)	I-y: **Jan-Feb** 180-210 II-y: **90-120** III-y: **180-225**	2012/8
							450 (II-y)	50	8(12)	**Ma-Jun** 300-360 **150-240** **300-360**	
							450 (III-y)	50	8(18)	**Se-Dec** 180-275 **90-150** **135-180**	
71	Oil palm (90x900x900, triangular)	Navsari	SG	-	-	NA	450	50	8(18)	Four equal splits of 2400 g/t/y of NK during May, Jun, Oct and Nov	2012/8
72	Onion/*Pilli patti* (10x15)	Navsari	SG	39	35	240	80	80	8	20 min Jan-Feb 25 min March 40 min April	2010/6

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
73	Onion/White Gujarat (10x15) Raised bed (Top width-90 cm, Furrow-30x20 cm)	Navsari	SG	30	-	403	120	100	8	40-50 min Dec-Jan 60-70 min March-April (5 equal splits of 80 % RDF of NK and 1500 l/ha banana pseudostem sap at 10 DI, starting 15 DAP)	2012/8
74	Onion/*Pilli patti* (seed production) Two rows at 50 cm on raised bed (Top width-100 cm)	Junagadh	Su	25	20-25	1:3.24	145	50	4	47 min / every day	2011/7
75	Papaya/ Madhubindu (250 x 250)	Junagadh	Sau	27	20	133	250	250	8	180 min. Oct.- Feb., 300min. onward 20 % fertilizer saving	98-00/37
76	Papaya/ Madhubindu (250 x 250)	Anand	MG	20	-	284	250	45 cm Away from of stem on both side	4(2)	310-330 min Sept-Feb 640-650 min Mar-harvest (16 equal splits of 80% RDF at 15 DI, starting at 60DAP, 20 % fertilizer Saving)	2008/4
77	Papaya/ Madhubindu (250 x 250)+ BPM(50 µ,20% coverage)	Navsari	SG	40	-	66	250	30 cm away from Stem on both side	8	20-30 lit/plant –winter 30-50 lit/plant- Summer (14 equal splits of NK at 15 DI, starting 30DI)	2010/6

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
78	Papaya/ Madhubindu (210x190)	Navsari	SG	20	32	272	210	30 (both side)	8(2)	40-60 min Aug- Sept 60-80 min Oct-Feb 120-130 min March-harvest (12 equal splits at 15 DI, starting after 45 DAP, 20 % N saving)	2011/7
79	Pearl millet (summer)/GHB-558 (45x10)	S K Nagar	NG	8-10	40-45	51.4	90	45	8	55 min Feb-March 70-80 April-May (25 basal and 75 % NP in three equal splits at 15,30,45 DAS)	2011/7
80	Pointed gourd /local (200x100)	Navsari	SG	37	47	180	200	100	4	70-80 min Winter 80-155min Sumer	2011/7
81	Pomegranate / *Ganesh* (6x 6)	Dehgam	NG	49	-	-	600	600	8 (2)	330 min. Oct. – Jan, 420 min. Feb- March	95-99/36
82	Potato/ *Khufri Badsah* (30 x 60)	S.K. Nagar	NG	-	12	-	90	50	8	25-30 min. – Nov. – Feb. 35-40 min.- March onward	01-03/40
83	Potato/ *Khufri Badsha* (45 x 15) (Fertigation)	S.K. Nagar	NG	-	13	NA	45	50	4	45 min – Dec. - Jan 68 min - Feb. – March, (240 N/ha in 4 equal splits)	95-96/33
84	Potato/ *Khufri Badsha* (60 x 120)	Deesa	NG	20	22	NA	120	60	4	40% N saving	96-98/34
85	Potato/ Khufri Badsha (60)	Deesa	NG	44	26	63	60	60	4	45 min - Dec. - Jan 68 min- Feb. - March	90-92/29
86	Potato/ *Khufri locker* (45)	Anand	MG	43	29	132	90	45	4	50 min	01-03/40

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
87	Potato/ *Khufri Badsah* (4 rows(30x20) on bed of 150 cm	Dessa	NG	39	55	313	Two laterals on bed	NA	NA	NA	2009/5
88	Round melon (*Tinda*) Summer	Navsari	SG	5-7	-	99	200	100	8	165 min March 195 min April 210 min May –harvest (10 equal splits of NK at 10DI, starting from 10 DAS)	2011/7
89	Rose/Gladiator (100 x100 x120)	Navsari	SG	17	54	301	300	100	8	150-180 min. Winter, 210-270 min. Summer 25 % fertilizer saving Drip + BPM	96-00/36
90	Sapota/ *Kali patti* (1000 x 1000)	Paria	SG	21	17	15	1000	1-2 m away from trunk	4 (2-4)	240 min. winter 420 min. summer	92-95/32
91	Sapota/ *Kali patti* (1000 x 1000)	Paria	SG	43	-	130	1000	1-2 m away from trunk	8 (8)	60 min. winter, 90 min. summer	96-00/37
92	Sapota/ *Kali patti* (1000 x 1000) (3 to 6 year old plantation)	Navsari	SG	40	8 - 37	NA	1000	1 m away from trunk	8 (2-4)	150-420 min	94-97/34

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
93	Sapota (10Year)/ *Kalli patti* 1000x1000	Navsari	SG	14	-	121	1000	40	8(8) 2 m away	240-300 Winter 480-600 Summer	2011/7
94	Spider lily/local (90x30)	Navsari	SG	40	-	728	180	90	8	75-100 Winter 60-80 Summer	2011/7
95	Sugarcane/ Co. 6304 (100 x 50)	Navsari	SG	41	48	84	100	50	4	20-32 min. up to June	89-92/29
96	Sugarcane/ Co. 6304 (60 x 120 Pair)	Navsari	SG	46	17	49	180	60	4	NA	95-96/33
97	Sugarcane/ Co. 6304 (60 x 120 Pair)	Navsari	SG	40	17	NA	180	60	4	5 equal split at monthly interval (50% NPK saving)	95-96/33
98	Sugarcane/ Co.6304 (90)	Navsari	SG	-	-	-	90	60	4	Inter crop: Garlic or Onion or Cabbage	98-99/36
99	Sugarcane/ Co.91132 (60 x 120)	Navsari	SG	38	23	139.7	180	60	4	Oct.-Dec.-25 min. Jan.-March-32 min. , April-June – 35 min. July-Sept.-20 min.	99-01/38
100	Sugarcane/ (60x120 Pair)	Navsari	SG	-	-	-	180-	60	4	10 equal splits of 60 % RDF of NK and 500 l/ha banana pseudostem sap at an interval of 10 DI, starting 60 DAP)	2012/8
101	Smooth gourd/ Chetak (100 x 200) + STM (2.5 t/ha)	Navsari	SG	50-55	-	80	200	100	4	30-60 min Oct-Jan 60-120 min Feb-up to harvest	2006/2
102	Tomato/ Avinash (50 x 50 x150)	Navsari	SG	33	37	320	200	100	8	40 % fertilizer saving	95-96/36

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SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	Spacing (cm)		DD (Nos.)	Schedule	Y/ AGR No.
							Lateral	Dripper			
1	2	3	4	5	6	7	8	9	10	11	12
103	Tomato/ Indo-American (60 x 90) (Drip + BPM)	Khandha	MG	57	60	170	90	120	4	60 min. - Nov.- Jan. 90 min. - Feb.- March	94-96/32
104	Tomato/ Mahabaleshwer (45 x 45 x 75)	Anand	MG	60	28	NA	120	60	4	50% NPK saving	96-98/35
105	Tomato/ *Rupdi* (50 x 100) Drip Drip + STM Drip + BPM	Navsari	SG	 - 45 45	 43 57 52	 94 153 201	100	100	4	90 min. -without mulch 45 Min. -with mulch	90-92/28
106	Tomato (90x60)	Junagadh	Sau	-	-	167	90	60	4	100-110 min	5/2009
107	Tuberose/ Duble (30 x 120)	Navsari	SG	-	42	186	120	60	8	50 min. Oct.- Feb., 85 min. onward	99-00/37
108	Turmeric/ *Sugandham* 3 rows (30x20) on raised bed of 90 cm of top width followed by a furrow of 30 cm depth	Navsari	SG	32	20-25	453	135	100	8	45-60 min Sept-Dec 50-75 min Jan-March (9 equal splits of 50 % NK at 15 DI, starting cessation of monsoon, 20 % NK saving)	2012/8

DD: Dripper discharge in lph, (Nos.): Numbers of dripper, NR/ mm: Net return/ha-mm water used, MT: microtube, WS: % Water saving, YI: % Yield increase, Y/ AGR No.: Year/ AGRESCO No., BPM: Black plastic mulch, STM: Sugarcane trash mulch, GM: Grass mulch, AD: Alternate day

General instruction for drip technologies:

1) The system should be operated on alternate day at 1.25 kg/cm^2 pressure, 2) Filter unit should be cleaned regularly,

3) System should be flushed thoroughly after each event of fertigation and 4) System should be checked frequently for leakage

IV. MINI SPRINKLER TECHNOLOGY

This system was evaluated, for 7 different crops in three agroclimatic zones (Table 16). While this system was not found to be remunerative in the case of lucerne at Anand, in other crops, the per cent saving in water varied from 9 (onion) to 25 (safflower). The per cent increase in yield ranged narrowly (15 to 51 %).

Table 16: Minisprinkler technologies

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	No. of Irri. (D:mm)	Sprinkler spacing (m)	Schedule	Y/ AGR No.
1	2	3	4	5	6	7	8	9	10	11
1	Banana / Basarai (150 x 150)	Navsari	SG	-	-	-	-	-	Intercropping of turmeric in minisprinkler irrigated banana is not advisable	99-00/ 37
2	Garlic/ GAUG-1 (15 x 10)	Navsari	SG	21	37	NA	10	2 x 2	I AS, II: 10 DAS, rest 8 at10-15 DI (herbigation for effective weed control)	96-98/35
3	Garlic (15x10) with Gypsum (2 t/ha)	Navsari	SG	20	51	224	12(50)	2.5x2.5	10 DI in Nov-Jan 8 DI in Feb- up to harvest (5 equal splits of N as urea at 10-12 DI, starting 15 DAS, 20% N saving)	2009/ 5
4	Green gram/ K-857 (30)	Navsari	SG	21	15	NA	3-7	2 x 2	Not economical	93-94/32
5	Groundnut (S)/ GG2 (30)	Navsari	SG	38	37	52	9	2.5 x 2.5	I at AS, II,III- 8-10 DI, rest 12-14 DI	95-97/34
6	Groundnut (S)/ GG2 (30)	S.K. Nagar	NG	18	21	27	20	3 x 3	First 10 irrig. at 5-6 DI, rest 4-5 DI	94-95/31
7	Lucerne/ A-2 (Broad casting)	Anand	MG	18	20	-	-	-	Minisprinkler not advisable	90-92/29
8	Onion / Gujarat red (15 x 20)	Navsari	SG	42	23	200	5	2 x 2	I - AS, II- 6 to 7 AS, rest at 15 DI (20 % N saving)	03-04/1

SN	Crop / Variety (Spacing: cm)	Location	Region	% WS	% YI	B:C or NR/mm	No. of Irri. (D:mm)	Sprinkler spacing (m)	Schedule	Y/ AGR No.
1	2	3	4	5	6	7	8	9	10	11
9	Onion/ Gujarat Red (20 x 15)	Navsari	SG	9	20	73	10	2 x 2	First 3 irrigation at 10 to 12 DI and Rest 6 to 7 weekly interval.	90-92/29
10	Onion	Anand	MG	26	18	90	10(50)	2.5x2.5	1st irri of 80mm 2nd – 6-7 DAP 3rd -8th 12-15 DI 9th – 10th 8-10 DI (5 equal splits of 50% N as urea at 10DI, starting from 30 DAP)	2010/ 6
11	Potato/ Khufri Badshah (30)	SK Nagar	NG	35	17	57	12	3 x 3	8 DI	95-97/34
12	Safflower/ Bheema (45)	Navsari	SG	25	15	NA	7-9	2 x 2	Not economical	

DAS Days after sowing
DI Days interval
S Summer
WS % Water saving
YI % Yield increase
SG South Gujarat
NG North Gujarat
MG Middle Gujarat
Y/ AGRESCO No. Year / AGRESCO No.

Note: Operating pressure: 1.5 to 1.75 kg/cm^2,
operating time depends upon discharge of minsprinkler

V. SPRINKLER TECHNOLOGY

Techno-economic viability of this system was evaluated for 13 different crops which has resulted in release of 23 recommendations for four agroclimatic zones (Table 17). The water saving through sprinkler ranged from 11 to 69 per cent, while that of increase in yield was up to 57 per cent.

Table 17: Sprinkler technologies

SN	Crop / Variety	Location	Region	% WS	% YI	B:C/ NR/ mm	Depth (mm)	Schedule	Y/ AGR No.
1	2	3	4	5	6	7	8	9	10
1	Bhindi	Navsari	SG	28	23	81	50	10 to 18 DI	NA
	Cabbage / Golden acre	Thasara	MG	17	10	123	40	10 - 12 DI	00-03/39
2	Cabbage	Navsari	SG	40	3	121	50	11 to 14 DI	89-91/28
3	Cauliflower/ Pus Dipali	Navsari	SG	35	12	115	50	11 to 14 DI	93-95/ 31
4	Cowpea(S)/ Pusa Falguni	Navsari	SG	19	3	29	50	9 to 10 DI: March 7 to 8 DI: April-May	90-92/29
5	Fenugreek/ Local	Jagudan	NG	29	35	29	40	7 DI: Dec.-Jan. 15 DI: Feb. 11 DI: March	88-90/28
6	Gram / ICCC 4	Khandha	MG	38	46	35	50	Branching, Flowering and Pod formation	96-99/35
7	Gram	S.K. Nagar	NG	11	31	34	50	12-14 DI	NA
8	Gram	Vyara	SG	69	57	24	50	Sowing and Branching	90-92/29
9	Groundnut(S)	S.K. Nagar	NG	23	14	34	40	10 DI	91-93/29
10	Groundnut(S)/ GG-2	Anand	MG	21	42	18	40	I : DS, II – III :14-17 DI, IV – XI: 8-10 DI	NA
11	Groundnut(S)	Vyara	SG	-	40	17	40	7-8 DI	90-92/29
12	Groundnut(S)/ GG-2	Navsari	SG	24	30	28	50	10 DI	NA
13	Lucerne/ A-2	Anand	MG	16	27	6	50	11-12 DI :Till Jan., 8-10 DI: Feb., 7 DI: March-April	NA

SN	Crop / Variety	Location	Region	% WS	% YI	B:C/ NR/ mm	Depth (mm)	Schedule	Y/ AGR No.
1	2	3	4	5	6	7	8	9	10
14	Lucerne/ A-2	Navsari	SG	50	-	25	50	17-19 DI:Dec.-Feb. 10-13 DI:Mar.-May	91-93/31
15	Lucerne/ A-2	S.K. Nagar	NG	28	8	17	40	First 10 irri.: 10 -12 DI, Rest at 5-6 DI	94-95/32
16	Maize/ GM-1	Godhra	MG	41	36	12	40	I = 0.75 IW/CPE	90-92/29
17	Potato/ Kufri Badshah	Deesa	NG	46	4	47	40	I: AS, II: 8 DAS 12-14 DI: Feb., 8 DI: March	89-91/28
18	Sugarcane/ Co. 6304	Navsari	SG	42	5	47	50	20-25 DI	88-91/29
19	Wheat	Vijapur	NG	31	18	26	40	Ample water: 15 DI: up to Feb., 10 DI: Feb. –March Water constraints: 21 DI up to Feb., 10 DI: Feb. –March	89-92/29
20	Wheat/ Lok-1	Khandha	MG	32	36	54	50	I : AS, II:17 DAS, III/ IV = 13-14 DI, V/VII: 10 DI	93-95/31
21	Wheat	Navsari	SG	62	13	43	50	12 DI	NA
22	Wheat / Lok 1	Danti	SG	38	-	-	50	I: AS, II: CRI, III-Keen height, IV: Boot leaf	96-99/37
23	Wheat / Lok 1	Thasara	MG	56	-	31	50	-	97-99/36

Note: Sprinkler spacing: 1200 x 1200 cm
Operating pressure: 2.75 kg/cm^2

B:C Benefit : Cost ratio
YI % Yield increase
NR/ mm Net return per mm of water used
Y/ AGRESCO No. Year / AGRESCO No.

WS % Water saving

VI. MULCHING TECHNOLOGY

Mulching is an important aspect in water management be it rainfed or irrigated. Apart from the prime function of moisture conservation, mulching also moderates the soil temperature, restricts upward movement of salts, suppresses weed growth, mitigates soil borne pest and disease problems through solarization and improves soil productivity. The beneficial effects of mulching greatly depend upon the kind, types, colour and season of mulching. Concerted efforts are being made at different research centres of the university to evaluate mulching effect on soils and crops (Tables 18). In mulching, the total 36 technologies were developed covering 13 different crops of Gujarat. With an exception of old plantation of coconut at Mahuva, in rest of the crops and location an increase in yield was ranging from 10 per cent in Okra (Thasra), Sugarcane (Khandha) to as high as 97 per cent in *ber* at Danti.

Table 18: Mulching technologies

SN	Crop / Variety	Location	Region	Mulch material	% WS	% YI	Addl. income (000'Rs /ha)/ B:C	Remark	Y / AGR No.
1	2	3	4	5	6	7	8	9	10
1	Banana/ Basarai	Navsari	SG	ST @ 10 t/ha	33	13	9.5	i) 60 % weed control ii) improvement in soil physical properties	87-91/28
2	Banana/ Basarai	Navsari	SG	ST @ 15 t/ha	40	49	44	-	91-95/32
				BP (100 μ)	35	18	10	50 % coverage	
3	*Ber*	SKNagar	NG	BP (100 μ)	-	25	1.5	For conserving the moisture after cessation of monsoon	NA
4	*Ber* / Gola	Danti	SG	BP (100 μ)	RF	97	-	Upward movement of salt was restricted, 40% coverage	00-02/39
5	Brinjal / Surati Ravaiya	Navsari	SG	BP (50 μ)	-	57	1:3.4	100 % coverage	97-99/36
6	Brinjal	Khandha	MG	BP (50 μ)	-	27	7.4	80% weed control	94-96/32
7	Brinjal	SKNagar	NG	Castor shell	-	19	3.7	Moisture conservation	92-94/30

SN	Crop / Variety	Location	Region	Mulch material	% WS	% YI	Addl. income (000'Rs /ha)/ B:C	Remark	Y / AGR No.
1	2	3	4	5	6	7	8	9	10
8	Brinjal	Achhalia	SG	GM @ 5t/ha	RF	44	5.0	i) Mulching 15 days after cessation of monsoon	93-95/31
				BP (50 μ)	NA	57	3.6	100 % coverage	
9	Chillies	Navsari	SG	ST @ 10 t/ha	NA	14	8	100 % coverage	93-95/32
				BP (50 μ)	NA	62	30	90 % coverage	
10	Chillies	Achhalia	SG	GM @ 5 t/ha	-	29	29.0	-	NA
				BP (50 μ)	20	29	23.0	One irrigation can be saved	
11	Cauliflower	Navsari	SG	BP GP YP	NA NA NA	33 21 15	18.0 8.0 3.0	75% weed control 33% weed control 59% more weed due to YP.	96-98/34
12	Castor	SK Nagar	NG	Castor shell @ 15 t/ha	RF	47	2.0	-	93-97/34
13	Castor	SK Nagar	NG	Mustard straw	-	10	NA	Rainfed crop	NA
14	Castor (R)	Navsari	SG	STM@ 5 t/ha	14-15	18	1:2.05	Six irri.(AS,2nd - 10DI, rest-22-25 DI)	2006/2
15	Castor	Tanchha	SG	BPM(50 μ)	-	51	0.235	Alternate furrow irrigation	2006/2
16	Castor (R)	Danti	SG	Grass mulch (5 t/ha)	-	12	1:2.05	-	2008/4
17	Coconut	Mahuva	S	BP/ coconut leaflet	-	-	-	In 40-50 years old plantation mulching is not benificial	94-97/33
18	Coconut	Mangrol	S	BP/ wheat straw/ stone pieces	-	-	-	In 40-50 years old plantation mulching is not benificial	93-96/33
19	Coconut / Dwarf orange	Mahuva	S	Wheat straw BP	- -	23 25	- -	-	93-99/36
20	Cotton / Hy-6	Khandha	MG	Wheat straw @ 10 t/ha	-	17	2.8	-	91-93/30
21	Cotton	Achhalia	SG	SM	RF	36	3.5	-	
				GM	RF	47	5.0	-	92-94/31
				BP	RF	58	-ve	-	
22	Cotton	Bharuch	SG	PM	RF	34	-	-	91-94/31

SN	Crop / Variety	Location	Region	Mulch material	% WS	% YI	Addl. income (000'Rs /ha)/ B:C	Remark	Y / AGR No.
1	2	3	4	5	6	7	8	9	10
23	Cotton	Danti	SG	BP	RF	93	40.5	BP reduces salinity effect and N requirement	93-96/32
				GM	RF	60	1.4	-	
24	Cotton	Navsari	SG	BP	50	20	NA	Alternate furrow irrigation with BP	NA
25	Ground nut (S) / GG2	Navsari	SG	7 μ TP	-	50	1:1.7	-	99-01/38
26	Ground nut (S) / GG2	Navsari	SG	7 μ TP	-	33	1 : 3.7	Groundnut sowing can be pre pounded	99-01/38
27	Pigeon pea	Bharuch	SG	BP (50 μ) + Tillage	-	24	-Ve	Moisture conservation	91-93/31
28	Marigold (African tall)	Navsari	SG	STM@5 t/ha or BPM (50 μ)	20	25	13-14	100% coverage	2006/2
29	Pigeon pea	Achhalia	SG	SM	RF	29	3.5	-	93-95/32
				GM	RF	50	5.8	-	
				BP (50 μ)	RF	78	2.7	-	
30	Pigeon pea	Achhalia	SG	BP (50 μ)	NA	34	-	-	92-94/31
31	Pigeon pea	Navsari	SG	ST @ 10 t/ha	-	47	5.3	-	NA
32	Okra	Navsari	SG	BP + 50 ppm NAA	-	25	50	90% weed control	95-96/35
33	Okra (S) / GoH-1	Thasara	MG	ST @ 10 t/ha	-	10	1:3.1		00-02 / 39
34	Okra (S) / *Parbhani Kranti*	Danti	SG	BP (50 μ)	NA	22	1:1.1	Coastal salt affected soil	02-03/40
35	Sapota (*Kali patti*)	Paria	SG	Grass Mulch	54	20-25	20-25	20 % area around trunk	2011/7
36	Sugarcane	Khandha	MG	ST @ 10 t/ha	34	10	NC	-	NA

ST Sugarcane trash
BP Black plastic
GM Grass mulch
TP Transparent plastic
GP Green plastic
SM Soil mulch
RF Rainfed
B:C Benefit: Cost ratio
YP Yellow plastic
NA Not applicable
NAA Naphthelene Acetic Acid

Success story: MIS + Mulching

In a water scarce state like Gujarat micro irrigation system (MIS) has special significance. In order to bring more and more area under MIS, GoG has established special company viz., Gujarat Green Revolution Company (GGRC). Because of the GGRC the area under MIS in Gujarat is steadily increasing (Fig. 7). The area under MIS up to March, 2012 in Gujarat has reached to 5.50 lakh ha. The success stories of drip, mulching, fertigation in banana and sugarcane as well as sprinkler irrigation in potato crops are presented here.

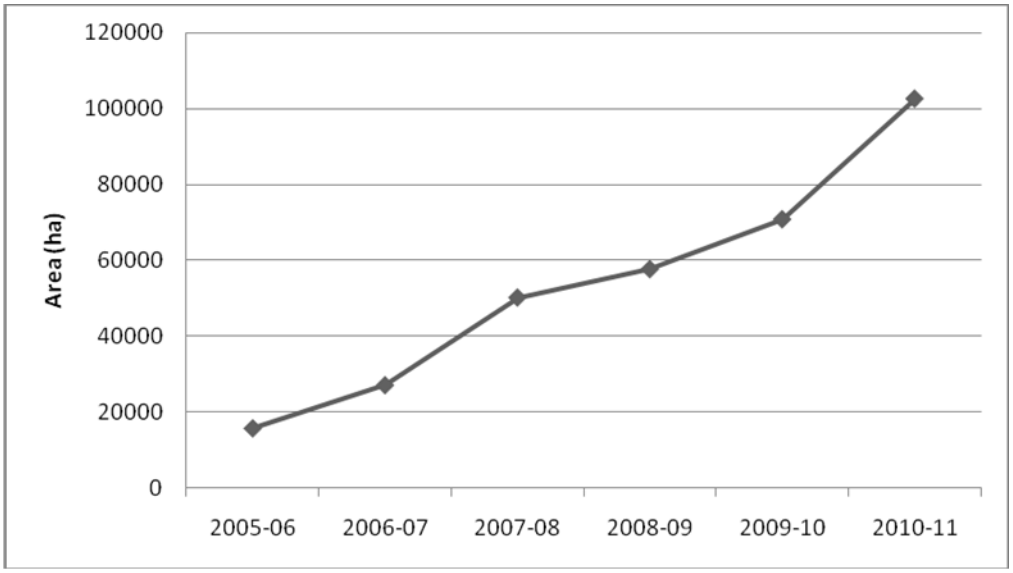

Fig. 7: Trend of area under MIS in Gujarat (Source: GGRC, 2011)

Drip, fertigation and mulching in banana and sugarcane

In Gujarat, banana (62,000 ha) and sugarcane (2,30,000 ha) are the two major cash crops predominantly grown in South Gujarat due to favourable agroclimatic conditions, presence of perennial irrigation facility and well established marketing network of farmers on co-operative basis. In both these crops, farmers were adopting conventional methods of irrigation and fertilizer application. Because of this, the productivity of both these crops was quite low *i.e.,* 35 t/ha of banana and 65 t/ha of sugarcane during 2002-03. For enhancing the productivity of both the crops, at state and national level concerted efforts were made to develop / standardize technologies like drip irrigation, fertigation, mulching *etc.*

As a result of these efforts, Soil and Water Management Research Unit, NAU, Navsari have developed/ standardized the technologies *viz.,* tissue culture plantlets,

drip irrigation, fertigation schedule and black plastic mulching for banana and paired row planting, drip irrigation and fertigation schedule for sugarcane crop. The significance of these technologies in enhancing productivity of both the crops was demonstrated to the banana and sugarcane growers through arranging package demonstrations (each of 0.4 ha) on farmers' fields along with training, farmers' days, *krishimahotsav,* TV talk *etc*. The results of demonstrations on farmers' fields reported in table 19 clearly indicate that with adoption of plasticulture technologies, farmers could save 20-40 % of irrigation water and fertilizer along with an increase in yield by about 15 to 25 per cent. The average additional net income per hectare realized by the farmers was ranging from Rs 60000 to 70000/ha with banana and Rs. 25000 to 30000 with sugarcane crop. If only area under drip irrigation in banana (10000 ha) and sugarcane (11000 ha) in Gujarat is considered, then the additional income generated per year by the farmers is about Rs 100 crores.

Table 19: The results of demonstrations on farmers' fields

SN	Particular	Unit	Banana	Sugarcane
1	Water saving	%	30-40	20-35
2	Fertilizer saving	%	20-40	20-30
3	Yield increase	%	20-25	15-20
4	Additional income over surface irrigation	Rs./ha	60000-70000	25000-30000

Drip and sprinkler in potato

Gujarat is one of the major potato producing states in the country. Potato crop is grown predominantly on light textured soils of North and Central regions of the state. This crop occupies around 40,000 ha area in the state with total production of 978 t and an average productivity of about 25 t/ha. Though, farmers have started adopting drip and sprinkler methods of irrigation in potato, yet the potential benefits are not fully realized by them. This is because of the reasons that they are over irrigating the crop and in most of the cases fertigation is not adopted. On account of this, the main purpose of water saving through use of either drip or sprinkler is defeated. Not only is this, but the logic behind providing subsidy for drip and sprinkler also lost. For realizing the full benefits of these systems, it is necessary to get feedback from the farmers about MIS. The adoption of drip/sprinkler on such a large scale (800 ha) in particular pocket that too in single crop of potato is not a common

phenomenon. In order to get feedback from the farmers, a survey of farmers who adopted MIS in potato was done. In this area, that the major source of irrigation water is personal tube wells (83 %) followed by participatory tube wells (9 %) and wells (6%).

The adoption of drip/sprinkler on such a large scale (800 ha) in particular pocket and single crop of potato is really astonishing. The basic motive behind this is to save irrigation water (100 %), improve quality of produce (83 %), increase yield (79 %) and reduce labour cost (48 %). Some of the farmers were of the opinion that adoption of drip/sprinkler will mitigate the problem of receding water table also (Table 20).

Table 20: Distribution of farmers based on the motive behind adopting drip/sprinkler

N=42*

SN	Motive	No. of farmers	%	Rank
1.	**Efficient use of water**	42	100	I
2.	**Improving quality of produce**	35	83	II
3.	**Increasing yield**	33	79	III
4.	**Reducing labour cost**	20	48	IV
5.	**Mitigate receding water table problem**	16	38	V
6.	**Protecting soil deterioration due to use of poor quality water**	2	5	VI
7.	**Save crop during drought**	1	2	VII

* One farmer did not reply.

For procurement of the irrigation system, 67 per cent farmers availed the benefit of subsidy. Among the respondents, about 53 per cent of them procured the system through bank loan. This is interesting to note that about 33 to 47 per cent farmers have installed the system without taking advantage of either subsidy or bank loan (Table 21).

Table 21: Distribution of farmers based on availing subsidy and bank loan

N=43

SN	Parameters	Category	No. of farmers	%
1.	**Subsidy**	Yes	29	67
		No	14	33
2.	**Bank loan**	Yes	23	53
		No	20	47

In order to understand the benefits of the system, farmers were specifically asked about improvement in quality of produce, early maturity and getting premium prices. The response in this regard by the farmers was positive as 44, 5 and 44 per

cent of them realized the benefit of improvement in quality, early maturity and premium price, respectively, due to adoption of drip/sprinkler system (Table 22).

Table 22: Distribution of farmers based on the quality improvement, maturity and premium price realized by the farmers

N=43

SN	Parameters	Category	No. of farmers	%
1.	**Quality improvement**	Yes	19	44
		No	2	5
		Not replied	22	51
2.	**Early maturity**	Yes	2	5
		No	15	35
		Not replied	26	60
3.	**Premium price**	Yes	19	44
		No	1	2
		Not replied	23	53

It is apparent from the above information that majority of the drip and sprinkler owners felt that saving in water was 50 -75 %. While 67 per cent farmers said that labour saving was in between 50 and 75 % in drip. In sprinkler, 38 per cent of the farmers were of the opinion that labour saving was less than 50 % (Table 23).

Table 23: Water and labour saving experienced by the potato growers of North Gujarat

N = 43

SN	Parameters	Category	Drip (N = 6)		Sprinkler (N = 37)	
			No. of farmers	%	No. of farmers	%
1.	**Water saving**	75 %	0	0	0	0
		50 – 75 %	6	100	27	73
		< 50 %	0	0	7	19
		Not replied	0	0	3	8
2.	**Labour saving**	75 %	0	0	1	3
		50 – 75 %	4	67	5	13
		< 50 %	2	33	14	38
		Not replied	0	0	17	46

At the time of survey, majority of the farmers have adopted sprinkler in this area since 2006-07. Most of the sprinkler owners were growing potato with sprinkler first time indicate that farmers are not fully aware about the use of MIS. The yield data reported in table 24 were collected from few selected farmers in potato. These values clearly indicate the increase in yield with drip and more so with sprinkler method of irrigation as compared to control. Though, farmers have adopted MIS, yet the volume

of water applied is on higher side (20-30 %). These suggest to educate MIS farmers about schedule of MIS so as to derive desired benefits of the system.

Table 24: Average yield and operating time of MIS by potato growers of North Gujarat

SN	Parameters	Drip	Sprinkler	Control
1.	**Average yield (t/ha)**	31 * (6)	39 (36)	29 (0)
2.	**Average net profit ('000 Rs/ha)**	52	96	51
3.	**Average water depth (mm/day)**	8 to 9	7 to 8	12 to 15

*( ) = data in parenthesis are per cent increase over control

Problems experienced by the farmers:

- Damage to riser/lateral pipe mainly by squirrel (24 %)
- Poor after sell service (30 %)
- Poor technical knowledge about MIS (36 %)
- Poor quality of MIS material supplied (valves, GI-PVC fittings, pressure gauge *etc.*) (39 %)
- High initial investment in drip as compared to sprinkler (more than double).
- Uneven distribution of water in case of sprinkler (27 %).

Suggestions and opinion of the farmers:

Some of the important suggestions/indications given by the farmers' which may be considered before taking any policy decision(s) are given below.

- Sprinkler system is cheaper than drip system.
- Wilt problem in later stage of the crop is less under drip than sprinkler and flood methods of irrigation.
- Sprinkler system is more suitable than drip system for farmers following potato–groundnut cropping sequence.
- Drip system is tedious in handling as compared to sprinkler system.

Conclusions:

- In potato, sprinkler system is preferred over drip system in North Gujarat
- There is need to maintain recommended plant population
- There is need to train the farmers
- This survey needs to be repeated after 2/3 years

VII DRAINAGE TECHNOLOGY

Though drainage is envisaged in project document of each and every command, seldom it receives due attention after commissioning of the project. As a result of this, the problems of water logging and secondary salinisation are of common occurrence in all the commands. The time required to appear these problems and their severity vary with soil type, cropping system adopted by the farmers, maintenance of the canals and presence of net work of natural drains in the command areas. In Ukai-Kakrapar command (UKC) area, 15 per cent of land is actually suffering from these problems and another 25 per cent land is critical mainly due to high clay containing soils, heavy rainfall, prevalence of high water requiring crops like paddy, sugarcane *etc*. A study conducted on impact of high water table on sugarcane yield indicated 31 per cent reduction in the productivity (Table 25). Further, during mid 1980s drainage study was initiated in Chalthan Sugar Factory area which indicated increase in yield of sugarcane, paddy, gram and Indian bean to the extent of 35, 19, 32 and 50 per cent, respectively (Table 26). Subsequently, in collaboration with ILRI, Wageningen, The Netherlands large scale demonstration on farmers' fields were laid out in a block of 50 ha and the techno-economic details are given in table 27.

Table 25: Sugarcane yield in high and low water table conditions

Water table condition	Yield (t/ha)		% decrease
	Range	Mean	
High	73.5 – 101.0	78.0	31.2
Low	97.3 -145.0	113.3	-

Source: Raman (1999)

Table 26: Yield levels of different crops in control and drainage blocks

Crop	Yield (t/ha)		% increase
	Before drainage	After drainage	
Sugarcane	68.0	91.7	34.8
Paddy	3.38	4.04	18.7
Gram	0.83	1.10	32.0
Indian bean	0.50	0.75	50.0

Source: Raman (1999)

Table 27: Economics of drainage systems

Parameters	**Control**	**OSSD**	**Control**	**CSSD (Spacing 45 m)**
Crop	Paddy	Paddy	Sugarcane	Sugarcane
Yield (t/ha)	2.2	3.8	78	105
Water table (bgl in m)	0.55	0.88	0.35	0.46
ECe (dS/m)	16.30	12.30	5.0	1.20
Cost of system installation (Rs/ha)	-	8000	-	20400*
Cost of cultivation (Rs/ha)	11000	16200	31286	41143*
Gross income (Rs/ha)	12980	22420	63555	85500
BCR	-	2.93	1.03	1.70
Internal rate of return (%)	-	114.5	-	58
Pay back period (years)	-	2	-	3

Source: IDNP Team, (2003)

* The total cost of cultivation and gross income are converted from 14 month growing period of the sugarcane crop to a yearly basis.

OSSD: Open subsurface drainage CSSD: Closed subsurface drainage

Success story: Subsurface drainage

Considering an improvement in yield of sugarcane and paddy along with decrease in water table and soil salinity in pilot area, farmers of UKC have adopted drainage technology even by bearing 100 per cent cost of drainage system under the technical guidance of Soil and Water Management Research Unit, NAU, Navsari. The taluka wise distribution of the farmers who adopted SSD technology is given in table 28.

Table 28: Taluka wise distribution of farmers and area covered under SSD

SN	District	Taluka	No of farmers	Area(ha)
1	**Surat**	Valod	2	3.20
		Kamrej	12	11.92
		Olpad	20	36.82
		Kosamba	3	7.3
		Bardoli	6	20.7
2	**Bharuch**	Ankleshwar	3	20.0
		Hansot	6	9.90
3	**Navsari**	Navsari	5	9.5
4	**Tapi**	Mandvi	1	1.75
Total			**58**	**121.11**

After adoption of CSSD system, farmers could harvest 200,150,218,307,368 and 87 per cent higher yield of sugarcane, paddy, brinjal, bottle gourd, cauliflower and okra, respectively, as compared to the yield level before installation of the system. An increase in crop yield is due to lowering of ground water table by 20 cm annually and reduction in soluble salt content in soils. Though the farmers are ready to adopt the drainage technology, yet following problems discourage the farmers in adoption of the drainage technology. In order to mitigate these problems, following measures are being taken up by the Navsari centre.

SN	Problem	Measures taken up by the Navsari centre
1	Unavailability of corrugated PVC pipe in small quantity in local market	Navsari centre through Revolving fund purchase about 2000 to3000 m of corrugated PVC pipe per year and sell it to the needy farmers.
2	Absence of agency providing technical know-how of drainage technology at field level	Navsari centre extent all the possible technical guidance with the limited man power available with the centre.
3	Adoption of drainage technology in scattered manner	There is need to activity involve sugar cooperative for adoption of drainage

		technology on mass scale *i.e.,* block basis. -In this regards, Maroli, Chalthan and Sayan sugar cooperatives have submitted proposal to RKVY to bring about 1500 ha area/year under SSD system.
4	Maintenance of CSSD system particularly collector drain	- There is need to have some agency to take care of maintenance of the system. For this drainage societies can be formed on the line of *Piyat Mandalies.*
5	Poor awareness about subsidy available for CSSD	The funding agency either at state or national level should bring the scheme to fore front and work in mission mode .
6	Inadequate expert manpower	HRD through national and international trainings.

The farmers of UKC have not simply adopted the CSSD in affected area, but they are also doing some modifications in the system, so as to meet their site specific requirement. One such case is reported here.

The subsurface drainage has been installed on the fields of Shri Arvindbhai Patel and Shri Bharatbhai Patel at village Mulad, Taluka Olpad, District Surat of Gujarat state in the command of *Kosamba* branch under *Ukai Kakrapar* irrigation project with the technical support from AICRP on WM, Soil and Water Management Research Unit, Navsari Agricultural University, Navsari (Gujarat). The soils are heavy with 55 per cent clay. Earlier farmers used to grow cotton and pigeon pea. However, they shifted to sugarcane and paddy with the start of irrigation. The water logging and salinity problems appeared later on due to flat topography, over irrigation and low permeability of soil. The soil salinity was around 8-10 dS/m and ESP ranged around 18-20 before the installation of subsurface drainage system. As per University, threshold value of ESP for sugarcane crop is around 8 for the heavy soils occurring in the area. The University recommends application of either gypsum + biocompost (sugar factory waste) to control sodicity besides the subsurface drainage for waterlogged and salt affected soil. Farmers themselves did expenditure on the subsurface drainage system. The drain spacing for the system is 45 m and the cost of the system is around Rs.25,000/- per ha. They also applied gypsum at the rate of 6 t/ha.

The system works by gravity and drainage water disposed in to stream, which ultimately take it to *Tapi* river, is 2-3 km away from the farmers fields. At one of the manhole, which is closer to outlet, farmers have made provisions to put surface water into it, in the event of surface stagnation due to excess rainfall. The small silt basin is also provided and surface water is passed through silt basin before entering into manhole. The collector pipe thereafter is of rigid PVC pipe. Pump and pump stand are provided at outlet. Whenever required, fresh water is pumped from the stream/*Nala* and put into rigid collector through pump stand. The collector line is used as lift irrigation pipeline to irrigate the fields. Thus, farmers are using collector line for surface drainage, subsurface drainage and irrigation. Such innovations in subsurface drainage technology are required to propagate the technology at farmers' fields. Because of multiple uses of the system they are also taking care of the system. With successful operation of the system, the water logging problem has reduced and annul average water table has been lowered from 120 to 130 cm. The soil salinity has been reduced from 8-10 to 1.27-2.87 dS/m. The sugarcane yield has increased from 90 to 130 t/ha. The farmers are happy and express the satisfaction over the performance of dual purpose subsurface cum irrigation system.

Epilogue:

Water logging and secondary salinization are the menacing problems existing in each and every canal command area of India. Though, commendable research work in the field drainage has been done by Central Institute and SAUs, yet it has not been reached to the needy farmers to the extent it should have been. Hence, it is necessary to transfer the drainage technology to the farmers' fields in most effective way through active involvement of farmers, co-operatives, state and central agencies, NGOs, financial organizations *etc*., in mission mode .

REFERENCES

Anonymous (1988-89) NARP Status Report (Vol. I) of all the zones, GAU, Ahmedabad.

Anonymous (1994-95) Season and Crop Report of Gujarat State (Vernacular), Dept. of Agri., Ahmedabad

Anonymous (1996) Research Report – Water Logging and Soil Salinity in Ukai-Kakrapar Command, Causes and Remedial Measures, CSSRI, Regional Research Station, Anand (Gujarat)

Anonymous (2000) White paper on Water by IRMA

Anonymous (2002) Draft Gujarat State Water Policy, GoG, Gandhinagar

Anonymous (1983 to 2004) Joint AGRESCO Report, GAU, Navsari.

Anonymous (2005 to 2012) Joint AGRESCO Report, NAU, Navsari.

IDNP Team (2003) Subsurface Drainage Strategies to Combat Water Logging and Salinity in Canal Commands of Gujarat, SWMRU, GAU, Navsari (Gujarat)

Patel, A.M., Malik, M.S., Parikh, M.M. and Raman, S. (2000) Ground Water Table Fluctuation and Quality in Surat Branch of Kakrapar Command, SWMP, IDNP, Tech, Rep. 3, SWMRU, GAU, Navsari (Gujarat).

Raman, S. (1999) Water Management Research in Gujarat, SWMP Pub. 10, SWMRU, GAU, Navsari (Gujarat).

Raman, S. and Patil, R.G. (2005) Inpact of existing irrigation methods on water resources of Gujarat and measures to over come associated problems. In. Proc. National Seminar on Existing Agricultural Production in North Central India (Ed. Mishra et ai.). April 2-3, 2005, Indian Inst. Soil Sci., Bhopal. pp:42-54.

Raman, S., Patel, R.B., Tandel, A.D., Desai, N.D., Patel, P.A. and Patel, S.N. (1999) Surface Irrigation Technologies for Command Areas of South Gujarat *In*: Water Management Research in Gujarat (Ed. Dr. S. Raman), SWMP Pub. 10, SWMRU, GAU, Navsari (Gujarat).

Raman, S., Shekh, A.M., Patil, R.G. (GAU Team) and Velayutham, M., Shyampura, R.K., Sharma, J.P., Jain, B.L. and Giri, J.D. (NBSS & LUP Team) (2000) Natural Resources of Gujarat (Agroecological Data Base for Regional Planning), Jt. Publication, SWMRU, GAU, Navsari Campus, Navsari (Gujarat) and NBSS & LUP (ICAR), Regional Centre, Udaipur, (Rajasthan).

Srinivas Mudrakartha (2004) Ensuring Ruaral Water Supply in Gujarat : Resources, VIKSAT, Ahmedabad

Velayuthan, M., Mandal, D.K., Mandal, C. and Sehgal, J. (1999) "Agro-ecological Subregions of India for Planning and Development" NBSS Publ. 35, 372 p. NBSS & LUP, Nagpur, India.

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