Global Water Partnership
South Asia
India Water Partnership

Water & Climate Resilience Programme *(WACREP), India*

Report on Water Bodies and its Vulnerability with Basket of Sustainable Adaptation Options

Activity No. 3.7.1.C (Work Package-7) :*Assessment of vulnerability to climate change on water resources, commons, agriculture system and animal husbandry in Sinhar watershed in Bhinder Block (Vallabhnagar Tehsil) in Udaipur district of Rajasthan*

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WATER AND CLIMATE RESILIENCE PROGRAMME (WACREP)

Water and Climate Resilience Programme (WACREP) is an innovative initiative of Global Water Partnership (GWP) South Asia devised to improve the climate resilience of South Asian countries to withstand the impact of climate change. The major objectives of the programme are; (a) Develop and integrate 'no regrets' water security and climate resilience investments into their development plans, budgets and programs; (b) Identify solutions to address critical water security challenges to enhance climate resilience of countries and communities; (c) Build knowledge and capacity to enhance water security and climate resilience; and (d) Operationalize the GWP network with strategic allies and stakeholders to integrate water security and climate resilience in the development processes. More than 40 climate resilience interventions have been planned for the first phase (October, 2013 to March, 2015) of the programme. On successful completion of first phase, a set of new activities will be taken-up during the second phase.

The WACREP was launched at the India Water week in April 2013 by GWP-South Asia to improve the climate resilience of South Asian countries to withstand the impact of climate change through the implementation of 8 work packages aligned with GWP strategic goals. The programme is being implemented by the Country Water Partnerships of GWP-South Asia namely; Bangladesh, Bhutan, India, Nepal, Pakistan and Sri Lanka with the support of national and regional partners. The programme is also having synergies with Regional Institutions and initiatives on on-going climate change projects to ensure its effectiveness. The first Phase of WACREP Programme started in October 2013 will continue until March 2015. This programme under second phase will take up new set of activities with additional funding.

The report prepared by India Water Partnership (GWP-India) with the support of Action for Food Production (AFPRO) presents the status of water surface and groundwater resources *vis a vis* climatic vulnerability and impacts based on the study undertaken in a cluster of 10 villages of Sinhar watershed of Bhinder Block (Vallabhnagar Tehsil) in Udaipur district (sub-humid Southern part of Rajasthan) under **WACREP Work Package-7.**The report has also come up with some good sustainable adaptation options which can be adopted to cope with the climate change impacts.

Preface

Climate change is likely to impact disproportionately upon the poorest countries and weaker sections within countries thereby causing inequalities in health and wealth of people. Food security, clean water and eco-friendly environment are the basic need of the people.

Water, in all its dimensions, affects the ability of people to live and thrive in their environments across the globe. People living in rural areas are often facing difficulties in accessing safe and reliable water sources in order to maintainsustainable livelihoods. The impacts of climate changes on water resources are already visible in many parts of the country; in terms of changes in precipitation patterns and intensity, incidence of drought, widespread melting of snow and ice, increasing evaporation and water temperatures, and changes in soil moisture,runoff,and storage of surface and groundwater. Furthermore, increase in demand of water is growing constantly on one hand while shrinking water supplies cause pressure on water resources resulting in stresses to the delicate balance of hydrological system of the region. It is therefore, need of the hour to manage water resources using an integrated approach to mitigate social, economic and environmental impacts of climate change and to ensure solutions for good water governance especially in rural areas.

It has been a constant endeavour of AFPRO to comprehensively assess water resources of different regions of the country, predominantly in rural areas and to provide effective and workable solutions and interventions for improved and sustainable water structures best suited to the region and acceptable to the local communities. Agriculture and livestock are the major source of income and employment for rural masses in general and the tribal community in particular. Water plays a crucial role to supplement and strengthen this situation. Therefore an effort was made to assess the vulnerability to climate change in the context of water resources in a tribal belt of southern Rajasthan. The study was taken up in cluster of 10 tribal villages of Vallabhnagar Tehsil of Udaipur district which falls in sub-humid southern plain and Aravali hill region of Rajasthan. The status of water surface and groundwater resources *vis a vis* climatic vulnerability and impacts along with adaptive measures have been worked out and presented in this report and the analysis and application of the results are also illustrated. An effort has been made to consolidate all the efforts carried out so far in this field and serve as a ready reference for further work in this field. The report has been prepared jointly by **India Water Partnership (IWP)** and **Action for Food Production (AFPRO)**.

I am sure this report will prove to be an invaluable source of reference for the researchers, scientists and students engaged in climate change related studies, research and interventional programs. Moreover, the outcomes of this study and the suggestive adaptation measures can be applied in a similar agro-climatic region under any Government schemes or by other funding organizations.

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Acknowledgement

We sincerely thank the **Global Water Partnership-South Asia** (GWP-SAS) and **India Water Partnership** (GWP-India)) for providing all the encouragement, guidance and financial support for implementing the **Water and Climate Resilience Program** (**WACREP)**in Sinhar watershed of Bhinder Block (Vallabhnagar Tehsil) in Udaipur district of Rajasthan.This report entitled "***Water bodies and its Vulnerability with basket of Sustainable Adaptation options"*** is a part of the study undertaken under WACREP.

We convey our special thanks to **Dr. J. C. Dubey,** Sr. Geologist (Retd), Govt. of Rajasthan for his whole hearted cooperation and support to us for an in-depth interpretation and analysis of various data and also for his help in finalizing the report under reference.

The field level information and data were collected by **ApnaSansthan,** Udaipur. We are highly grateful to the entire team of ApnaSansthan for all their support and services.

Last but not the least; we would also like to convey our sincere gratitude and thanks to all men and women, especially the farming community of the selected 10 villages for their cooperation, support and extending a helping hand at every juncture of the study.

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Abbreviations

AFPRO	Action for Food Production
DFID	Department for International Development
E	East
FAO	Food and Agriculture Organization
FFCD	Fluidic Flow Control Device
Fig	Figure
Govt	Government
GWP	Global Water Partnership
GWPO	Global Water Partnership Organization
ha	Hectare
HH	Household
HP	Horse Power
IMD	Indian Meteorological Department
IWP	India Water Partnership
m	Meter
MANREGA	Mahatma Gandhi National Rural Employment Guarantee Act
mm	Millimetre
Mm^3	Million Cubic meter
MPUAT	MaharanaPratap University of Agriculture and Technology
MSL	Mean sea level
N	North
NAPCC	National Action Plan on Climate Change
RAPCC	Rajasthan Action Plan on Climate Change
WACREP	Water and Climate Resilience Program
WHS	Water Harvesting System
WRD	Water Resource Department

Executive Summary

The study on **"Water bodies and its Vulnerability *with basket of Sustainable Adaptation options"***for the semi-arid region of Rajasthan under **Water and Climate Resilience Program (WACREP)"**of GWP-South Asia was taken up in a cluster of 10 villages in Sinhar watershed of Bhinder block, Udaipur district, Rajasthan. The study area falls under semi-arid region of Rajasthan and characterized by large hilly forest cover and low area under plough. Maize (*Zea mays)* and Gaur (*Cyamopsistetragonoloba*) in *kharif* and wheat (*Triticumaestivum)*), gram (*Cicerarietinum*) and mustard (*Brassica juncea*) in rabi seasons are the major crops. Goat and buffalo are the major livestock reared in the project area. Irrigation is mostly through wells which depend on rainfall in the district.

The analysis of rainfall during the period 1980 – 2013 indicated that the area generally receives normal rainfall; however deficit rainfall is also frequent, followed by abnormal, excess and scanty. The deficits rainfall percentage is quite significant that indicates that there are wet and dry hydrologic phase of 4 to 5 years occur cyclically in the area.

The analysis of base line survey data indicated that agriculture and livestock are the major sources of employment and livelihood for the people in the study area. For drinking water there is more dependency on hand pumps and less dependency on common and private wells. Large numbers of open wells are unprotected, unlined and lying defunct in the area for various reasons. Heavy rains in few years and frequent drought in the subsequent years were the major climate havocs in the area. The reduction in the span of rainy season (No of rainy days) and changes in temperature were also observed.

The water resources in the area largely depend on monsoon rainfall which replenishes groundwater storages in wells and surface water in tanks and ponds, surplus water goes as runoff which is harvested through anicuts at places. The entire potential agriculture area is not covered under *rabi* crops due to shortage of water. The water management practices to minimize losses due to evaporation, leakage & breakage of irrigation channels, ensure storage capacity in wells and tanks through de-silting and enhancement of storage capacity is suggested.

The wells going out of use due to depleting of ground water table and for those wells under use, increased operational expenditures on one hand and higher cost of production of irrigated crops on the other hand are matters of concern. Intervention for increased ground water recharge and reduction in wastage of runoff, deepening of wells, de-silting, lining of water courses and other water management /conservation measure assume great importance.

The drainage represents dendritic origin and generally first and second order streams originate from low lying ridges and join the third order stream which is the main stream course in the area. The stream flow is from North-East to South- West direction. The area is part of catchment of Gomti River which joins a largest fresh water Jaisamand lake towards south-east of the area.

The rain-fed cultivation is generally done on the sloppy lands whereas irrigated land occupies valley portions and along stream courses. The irrigated area mainly depends upon groundwater which is obtained through shallow open dug wells located along stream courses.

Traditionally there are many methods being followed for water harvesting in Rajasthan. The structures and their designs vary in different parts of the state depending upon the location, topography and the rainfall pattern of that area. Mainly these structures include '***Khadin***', '***Tanka***', '**Nadies**', ***village ponds***etc. are popular in Western Rajasthan whereas '***Earthen bunds along stream courses with 'Haren' system***' is one of the popular water harvesting and irrigation system in Aravalli Mountain Region of Mewar area.

Groundwater is the major source for water in the area. The groundwater occurs under unconfined conditions and is in direct response to rainfall. The groundwater is used for drinking purposes and for irrigation. There are number of hand pumps through which groundwater is drawn for drinking water. For irrigation purposes open dug wells are used which are generally located along the stream courses and in valley portions.

The aquifers in the area comprise of hard rocks belonging to Pre Aravalli Banded gneissic formations. These rocks have secondary porosity and permeability developed by fractures and joints consequently have limited storage capacity.

The depth to water in the area varies considerably in different seasons. After monsoon the groundwater recharge is indicated with the rise of table and the wells are used for Rabi irrigation, consequently in post irrigation season water levels decline and in summer season water level reaches up to maximum depth thus leaving behind very limited groundwater storage in the well. The depth of hand pumps is generally 60 meters and usually these supply water in summer months.

The surface water resources are not only limited in number but their capacity to hold water is also inadequate. The evaporation rate in the region is significant and has been estimated as 1.5 to 2 meters annually; under these circumstances surface water bodies are vulnerable to climatic variability.

Groundwater is the major source of water for agriculture and drinking purposes. The groundwater occurs under three major constraints viz, low recharge, restricted porosity and permeability of aquifers, and significant fluctuation of water table. The terrain is undulating and hilly therefore, runoff generation from monsoon is high and very soon water flows out of the area consequently recharge is very limited. The wells which are located along stream courses are however recharged from the stream flows and water levels rise immediately, whereas in hilly region wells are recharged at much lower pace and rise in water table is also slow. The fluctuation in water table in different seasons is noteworthy. The groundwater occurs under unconfined conditions and corresponds directly to rainfall conditions. During low rainfall events aquifers are not recharged sufficiently to accomplish Rabi irrigation consequently result in low production of crops and poses a problem for drinking water in summer season. The irrigation command considerably reduces limiting the sowing area and crop production.

Most of the wells are shallow in depth and recuperation takes place after 24 hours to 48 hours, therefore sustainable yield from wells is not obtainable. Over exploitation of groundwater is carried out resulting in depletion of water levels. The open dug wells in the area are generally unlined and most of the wells are located along the stream courses. The heavy downpour during monsoon and inundation of streams causes threat to these open wells, these wells collapse or filled with silt and debris by the flood water and quality of groundwater also deteriorates. The wells become defunct and it takes time and money to renovate and make them operational.

The adaptive measures for improving water availability are generally site specific depending upon local geomorphic and hydrological conditions of the area. There are many proven practices for water harvesting, water conservation and water recharge. In some of the water stressed areas with small technical inputs and support of local farmers water availability has been significantly improved. The best practices adopted by farmers in different areas are important to study and may be tried with appropriate modifications.

Chapter–7 of this study report may be referred for "**Conclusion and way forward**".

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Contents

Chapter 1

Introduction and Background:

Rajasthan is geographically the largest and the eighth most populous state of India. Eighty per cent of the population depends on agriculture and 19 per cent on animal husbandry for their livelihood. Over two million families live below the poverty line. **R**ajasthan has barely 1.16% of the water resources of the country as against its share 11% in total geographical area. Average annual rainfall ranges from 150 mm in north-west part to 900 mm in south-east. Due to scarcity of surface water, agriculture production to a great extent in Rajasthan is critically dependent on the vagaries of monsoon and ground water resources. Land, human resources, crop and livestock activities are highly integrated and more or less cyclic in nature.

The National Action Plan on Climate Change (NAPCC) came in force to address the challenges posed by climate change along with the imperatives of poverty alleviation and economic growth for India. The focus of NAPCC is to improve the understanding of **climate science, adaptation, mitigation, energy efficiency and natural resource management & conservation.** As a follow-up, the state of Rajasthan also developed RAPCC (Rajasthan Action Plan on Climate Change).

The policy Framework as per the RAPCC on Water resources of Rajasthan, it is stated to adopt to a multi sectoral and integrated approach to water resources planning, development and management on sustainable basis taking river basin/sub basin as the unit by treating surface and sub-surface water with a unitary approach.

The suggested strategies for enhancing water harvesting capacity through different measures as per the RAPCC are:

- Construction of sub-surface barriers/sub-surface dykesetc., in the ‘overexploited’ and ‘critical’ categoryblocks.
- Construction of roof top rainwater harvesting structures in all government and semi governmentbuildings in urban areas and prominent buildings inrural areas.
- Storm rain water harvesting along roads, pavements in the prominent cities of the State.
- Recharge of wells in the fields of farmers by diverting the field water received from monsoon rainfall.

- Strengthening and monitoring network by replacing shallow wells by deep piezometeres.
- Increasing frequency of water level monitoring, ensuring availability of realistic data. Post irrigation monitoring to be done in addition to existing pre and post monsoon monitoring to enable correct assessment of ground water draft from the aquifers.
- Mass awareness program by publication and distribution of booklets/pamphlets regarding the water conditions in the concerned village

The major facets of climate variability and climate changes in the area are: **delay in the onset of monsoon, failure of monsoon, variability of monsoon rainfall, long break in monsoon and a real difference in the perseverance of monsoon.** All this changes impacts various sectors such as agriculture, water resources, forestry & biodiversity, human health, energy and infrastructure.

Keeping in mind the above, **Action for Food Production (AFPRO)** submitted a project proposal to **GWP** through **IWP** for assessing the vulnerability due to climate change for improving the livelihood condition of rural poor living in the semi-arid region of Rajasthan state through a program on "**Water and Climate Resilience**" under climate change scenario which has been subsequently approved by GWP/IWP for implementation on ground.

One of the important activities of this project was to conduct a study to assess the scenario of different Water bodies in the project area, its vulnerability due to climate change and to develop an adaptation framework so that the poor community can adapt it in their practices.

The report summarizes the status of different water source and its climatic vulnerability of ten villages covered under this Water and climate resilience program. The villages are located in VallabhnagarTehsil of Bhinderblock of Udaipur district of Rajasthan and situatedwithin Sinhar watershed forming a part of catchment of Jaisamand Lake. The natives belong mainly to tribal community, schedule caste and other backward class and their livelihood is largely dependent upon agriculture and rearing of livestock. The water sources are scarce and totally reliant on the monsoon rainfall. The area comprises of hilly and undulating terrain with small agriculture fields located along sloping lands, narrow strips of reclaimed lands within stream courses and also in small erosional valleys. The area is covered under semi arid climatic conditions and devoid of perennial source of water.

Table 1 Households and area of project villages

S. No.	Name of village	No. of households (as per census 2011)	Area of village hectares	Elevation above MSL meters
1	Beripura	65	50	475
2	Bhopakherda	164	324	498 (Maximum)
3	Dhawadia	303	614	424(Minimum)
4	Gajpura	57	81	474
5	Kapariokakheda	157	371	465
6	Khedaphala	209	181	458
7	Nagaliya	197	1296	462
8	Patia	58	82	496
9	Phoosariya	258	373	488
10	Rayala	129	132	468
Total		**1597**	**3638**	

An appraisal of water resources of the project area and impact of climatic variability has been carried out taking in to account the rainfall trend, status of surface water and groundwater, utilization of water resources for agriculture and drinking water purposes and landform and land use pattern of the area.

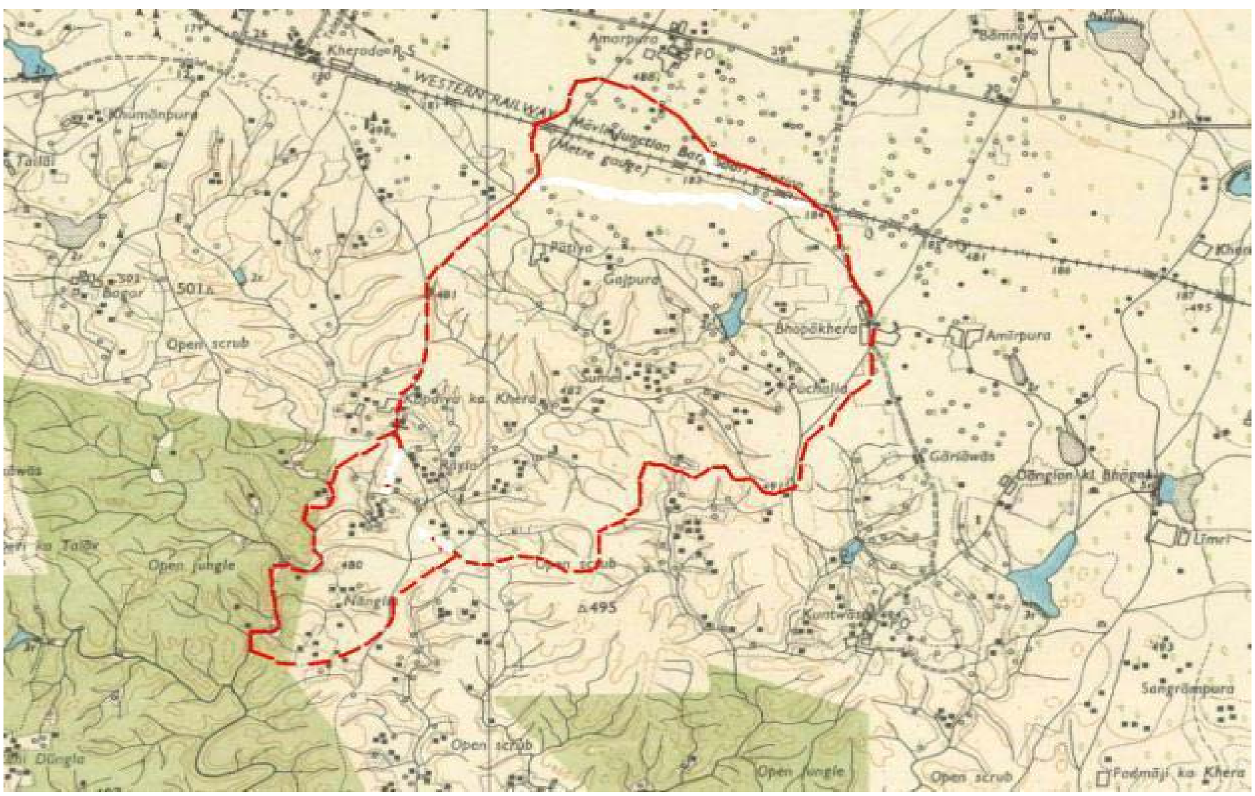


Fig 1 Location map from Survey of India sheet (45 L/2)

Chapter 2

Climate and Rainfall

The project area is covered under semi-arid climatic conditions with significant variations in the temperature and rainfall. The rainfall data of 34 years (1980-2013) from nearest met station, Vallabhnagar have been analyzed for working out average rainfall, trend of rainfall and deviation from average rainfall. The rainfall trend with 4 years moving average is depicted below.

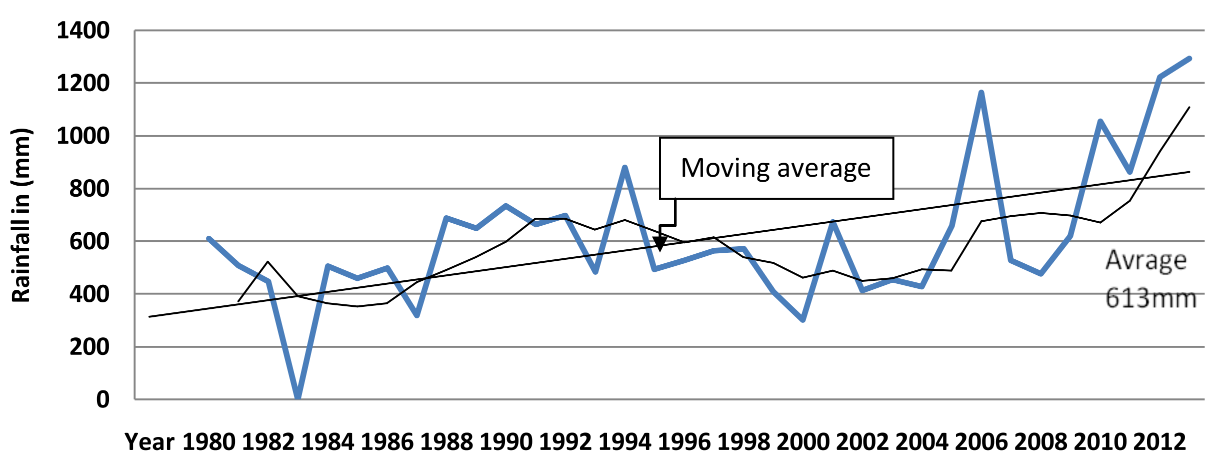


Fig 2 Annual rainfall (mm) at Vallabhnagar

The average rainfall from 1980 to 2013 is 613 mm. There is a considerable variation in number of rainy days in a year, the annual average rainy days are given below.

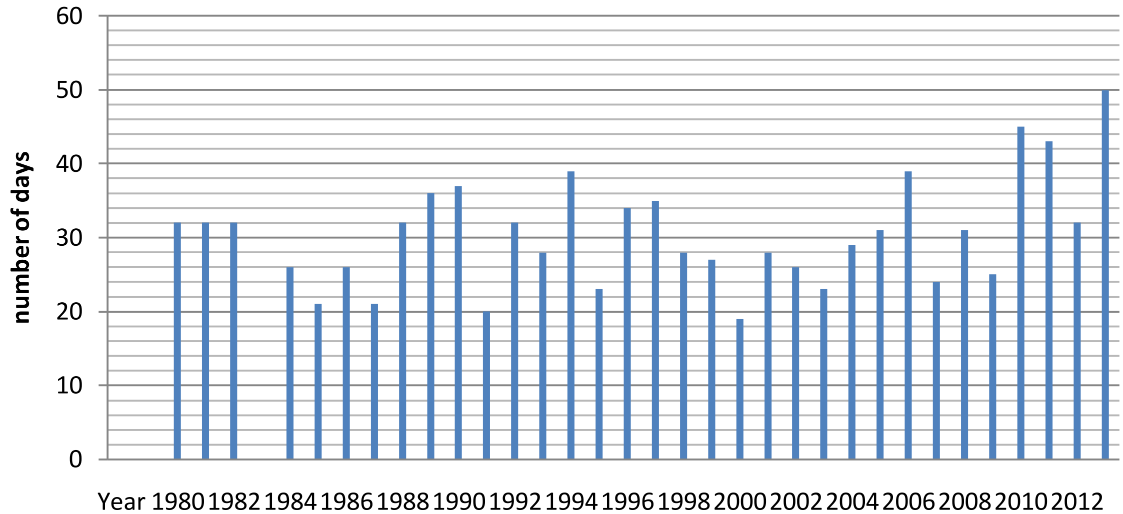


Fig 3 Number of rainy days at Vallbhnagar

The average rainy days for the period 1980 to 2013 i.e. for 34 years is about 30 days, however, maximum rainy days are between 30 to 35 days, followed by 25 to 30 days and 20 to 25 days. The year 1983 did not receive any rainfall and it was severe drought year.

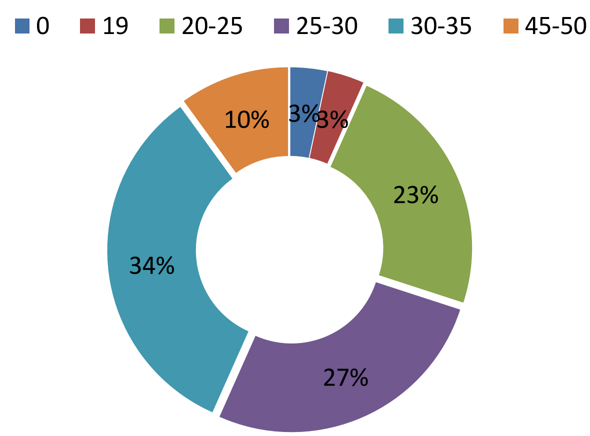


Fig 4 Number of rainy days at Vallabhnagar (%)

The deviation from average rainfall from average of 613 mm is given in the following figure.

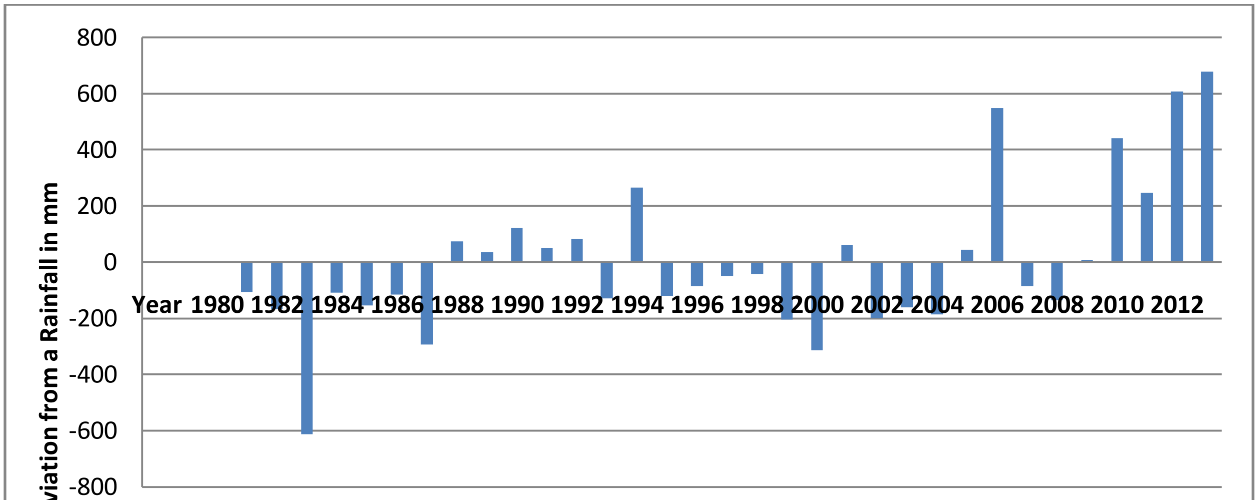


Fig 5 Deviation of annual Rainfall from Average Rainfall

The deviation of rainfall with respect to from average rainfall has been classified in to different categories (IMD), accordingly following classification is done:

Table 2 Categories of deviation of rainfall

S. No.	Categories	Deviation from average rainfall	Status in Vallbhnagar
1	Abnormal	60% or more	12 %
2	Excess	20% to 59%	9 %
3	Normal	19% to (-) 19%	44 %
4	Deficit	(-)20 % to (-) 59 %	32 %
5	Scanty	(-60 % or less	3 %

As per the above categories the deviation of annual rainfall from average rainfall at Vallabhnagar is depicted below.

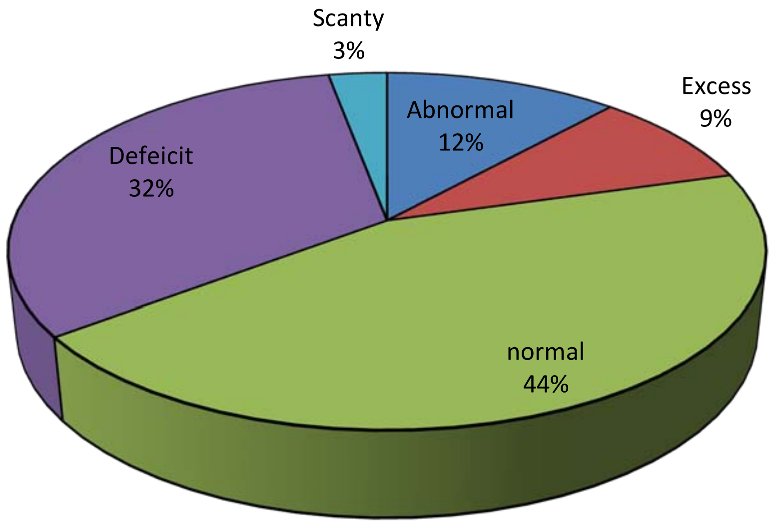


Fig 6 Deviation of rainfall from average rainfall (%)

It is evident from above analysis that the area generally receives normal rainfall; however deficit rainfall is also frequent, followed by abnormal, excess and scanty. The deficits rainfall percentage is quite significant that indicates that there **are wet and dry hydrologic phase of 4 to 5 years occur cyclically in the area.**

Chapter 3

Land form and land use

The project area depicts an undulating terrain comprising of erosional hills, drainage network and narrow valleys. The highest elevation of 492 meters above mean sea level is at Patiya village towards north of the watershed of the area whereas the lowest elevation 424 meters above mean sea level is at Dhawadiya village at south; forming a moderate general slope of watershed from north to south direction.

The drainage represents dendritic origin and generally first and second order streams originate from low lying ridges and join the third order stream which is the main stream course in the area. The stream flow is from North-East to South- West direction. The watershed is part of catchment of Gomti River which joins a largest fresh water Jaisamand lake towards south-east of the area. The Jaisamand Lake Catchment is located in the Udaipur district of Rajasthan. This Lake was originally created in the early 18th century to enhance the conservation of wildlife. Jaisamand Lake with a gross capacity of 414.6 Mm^3 and live storage of 296.14 Mm^3, is Asia's second largest artificial water storage reservoir. The gross basin area up to the Jaisamand dam site is 1787 km^2. The lake is also a prime source of water for the city of Udaipur located at a distance of about 52 km from the lake. Jaisamand is a prominent medium irrigation project with a cultivable command area of 160 km^2 downstream of the lake.

Land use

According to Food and Agriculture Organization (FAO), land use concerns the function or purpose for which land is used by the population; it can be defined as "the human activities that are directly related to land, making use of its resources or having an impact on them". For a given area at given spatial level, land use is described by specifying mix and particular pattern of land use types, the aerial extent and intensity of use associated with each type, the land tenure status, as well as natural and physical characteristics.

Land use is influenced by the characteristics of the local biophysical environment that determine, to a considerable extent, land suitability for a range of uses. The most important of them include local climate and weather conditions, local topography, bed rock type, soil type, water resources (surface and groundwater) and current state of quality of land.The land use pattern of the area depicts impact of all the stated features. The area is hilly and undulating consequently the waste land mainly comprising of stony and rock exposures is dominant in all the project villages. The Government and private waste land together forms almost 62 per cent of the area and another 2 per cent land is occupied by stream courses and pavements. These waste lands are basically uncultivable lands owned by both private and Govt but the private waste lands are known as 'Beeds' at local level. Only 21 per cent land is used for agriculture purposes wherein 16 per cent of land is covered under rain fed cultivation and only 5 per cent land is irrigated, which indicates that the water availability in the area is very limited. The forest cover is considerably insignificant and in many of the villages it is negligible. (Table - 3) The pasture land is also limited to only 5 per cent in the area.

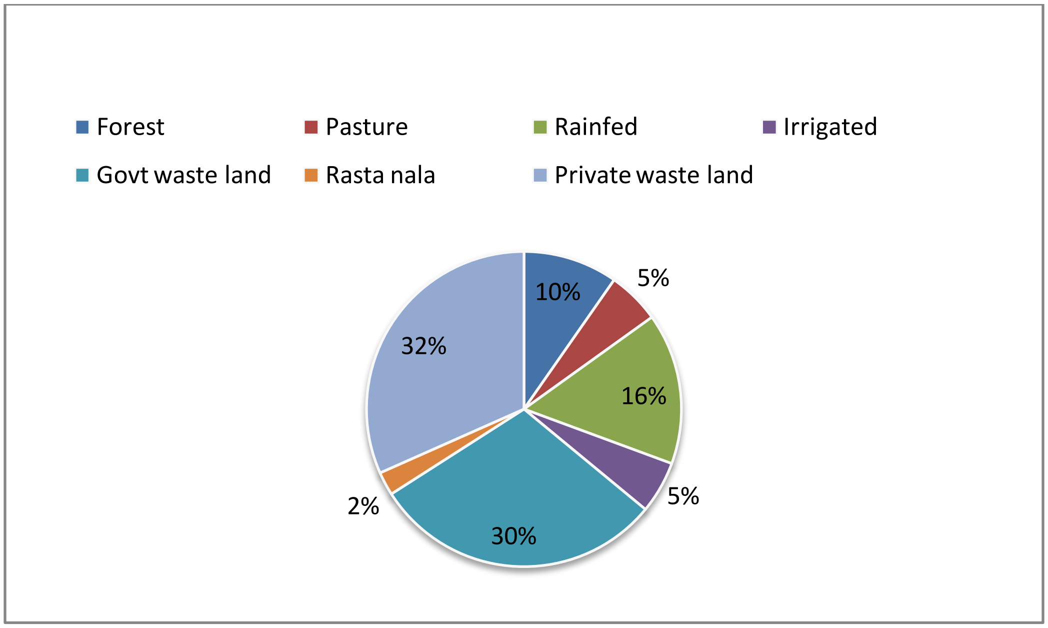


Figure 7 Land use pattern

The rain fed cultivation is generally done on the sloppy lands whereas irrigated land occupies valley portions and along stream courses.

Table 3 Land use data of different villages

Village	Forest	Pasture	Rain fed	irrigated	Govt. Waste land	Pathways drainage	Private waste land	Total (ha)
Beripura	0	9	10	6	0	3	22	50
Bhopakheda	0	17	155	55	18	2	77	324
Dhawadia	0	141	98	30	185	13	177	614
Gajpura	0	0	14	6	16	6	45	81
Kapariokakheda	0	0	22	12	334	1	14	371
Kheraphala	0	0	33	16	43	1	104	181
Nagaliya	353	0	79	18	427	55	382	1296
Paitya	0	0	14	10	15	3	50	82
Phoosariya	0	7	107	22	49	2	208	373
Rayla	0	22	33	20	3	2	72	132
Total	**353**	**196**	**565**	**195**	**1090**	**88**	**1151**	**3638**

(Source from Revenue Dept. 2014-15)

The irrigated area mainly depends upon groundwater which is obtained through shallow open dug wells located along stream courses.

Chapter 4

Water bodies and their status

Traditionally there are many methods being followed for water harvesting in Rajasthan. The structures and their designs vary in different parts of the state depending upon the location, topography and the rainfall pattern of that area. Mainly these structures include ‘Khadin’, ‘Tanka’, ‘Nadies’, village ponds etc are popular in Western Rajasthan whereas ‘Earthen bunds along stream courses with ‘Haren’ system is one of the popular water harvesting and irrigation system in Aravalli Mountain Region of Mewar area.

Surface Water

The project villages are generally located in the undulating and hilly terrain and therefore surface water storages are limited in number and extent. The monsoon runoff is generally stored in the small water harvesting structures (ani cuts) and in the village ponds and Nadis, wherein water remains for a few months after monsoon. The area does not have any minor or major irrigation project to support agriculture, though some of the water harvesting structures is used for lift irrigation for limited area. The following table depicts status of surface water bodies in the project villages.

Table 4 Surface water bodies in project villages

S. No.	Village	Details of Water Bodies					Structure details
		Anicut	Talab/nadi	Water availability in months	Submergence (ha)	Uses	
1	Beripura	-	1	3	0.35	For livestock	Construction by AS in 2010 under FFCD
2	BhopaKheda	-	2	3	2.34	For livestock	Constructed more than 100 years ago
3	Dhawadia	-	-	-	-	-	-

4	Gajpura	-	1	3	0.47	Recharge of groundwater	The village is also benefited by Patiyaanicut
5	Kapariokakhera	1	1	6	0.7	6 ha irrigation by lift	By panchayat
6	Kheraphala	-	-	-	-	-	-
7	Nagaliya	3	-	12	2.8	For livestock	Construction by WRD
8	Patiya	1	-	3	0.93	Recharge of groundwater	Constructed by Panchayat
9	Phoosariya	1	1	4	1.17	livestock	Constructed by Panchayat
10	Rayala	3	-	5	3.74	2.5 ha irrigation	Constructed by Panchayat

Groundwater

Groundwater is the major source for water in the area. The groundwater occurs under unconfined conditions and is in direct response to rainfall. The groundwater is used for drinking purposes and for irrigation. There are number of hand pumps through which groundwater is drawn for drinking water. For irrigation purposes open dug wells are used which are generally located along the stream courses and in valley portions.

The aquifers in the area comprise of hard rocks belonging to Pre Aravalli Banded gneissic formations. These rocks have secondary porosity and permeability developed by fractures and joints consequently have limited storage capacity. An appraisal of the groundwater conditions in the area has been attempted on the basis of well inventory of some of the representative wells form each project villages and interviews of the farmers.

Type of wells

The open dug wells are the traditional way of obtaining groundwater and therefore there are number of wells in each village which are generally old construction and most of them are unlined. (Annexure 1) A significant number of wells have become defunct also due to the reason that either these are collapsed or became dry due to lowering of water table. Most of the wells are unlined in the area.

The farmers have gone for shallow bore wells in some of the villages but generally bored wells are not very productive due to the fact that deeper horizons do not have promising aquifers.

Table 5 Number of wells and bore wells in different villages

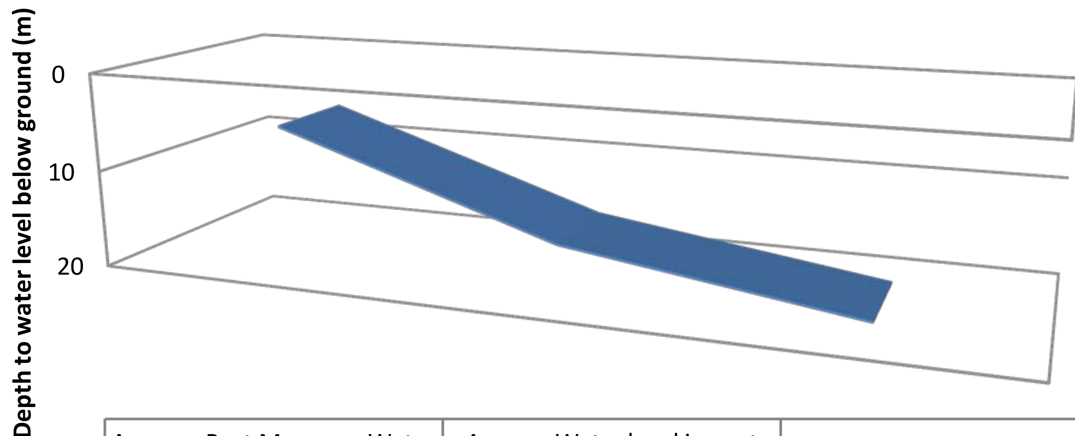
S. No	Name of village	Number of wells			Number of bore wells
		Total	functional	defunct	
1	Beripura	7	6	1	0
2	Bhopakheda	63	37	26	10
3	Dhawadia	75	41	34	0
4	Gaipura	11	9	2	3
5	Kapariokakheda	44	23	21	1
6	Kheraphala	20	16	4	0
7	Nagalya	53	41	12	1
8	Patiya	14	12	2	14
9	Phoosariya	82	40	42	7
10	Rayla	44	23	21	0
Total		**413**	**248**	**165**	**36**

The total depth of wells

The depth of wells generally depends upon their geomorphic location and hydrological conditions corresponding to encounter of water table. In valley portions and along stream courses the wells are of shallow depth as the water table is nearer to the ground level as compared to the hilly regions where it is deep therefore,the wells are also deep in this region. The depth of wells may vary from 8 meters below ground level to 34 meters.

Depth to water

The depth to water in the area varies considerably in different seasons. After monsoon the groundwater recharge is indicated with the rise of table and the wells are used for Rabi irrigation, consequently inpost irrigation season water levels decline and in summer season water level reaches up to maximum depth thus leaving behind very limited groundwater storage in the well.The average depth to water in different seasons in some of the representative wells of the area is depicted below



	Average Post Monsoon Water level	AverageWater level in post irrigation season	Average Water level in summer
Series1	6.05	15.61	19.85

Fig 8 Average Depth to water in different seasons

Water level fluctuation

The groundwater in the area occurs in unconfined conditions therefore exhibit direct response to the rainfall. During monsoon season the recharge is accomplished due to infiltration and by the effluent streams, however when irrigation commences the water level gradually declines due to regular pumping from wells by the summer time the groundwater storage exhaust which is indicated by the lowest levels of water table in the area. The fluctuation of water levels is significant in different seasons as recorded from different representative wells.

Table 6 Water level fluctuation in wells

S. NO	Village	Water level in Post monsoon	Water level in post irrigation	Water level fluctuation between post monsoon and post irrigation (3-4)	Water level in Summer	Water level fluctuation from post irrigation and summer season (4-6)	Total depletion of Water level from post monsoon to summer season (3-6)
1	2	3	4	5	6	7	8
1	Beripura	6	6.8	-0.80	8.3	-1.50	-2.30
2	Beripura	5	10	-5.00	18	-8.00	-13.00
3	Beripura	5	8	-3.00	12.2	-4.20	-7.20
4	Bhopakheda	10	20.5	-10.50	23.2	-2.70	-13.20
5	Bhopakheda	11	28.4	-17.40	30.35	-1.95	-19.35
6	Bhopakheda	10	23.7	-13.70	35	-11.30	-25.00
7	Bhopakheda	4	30.3	-26.30	34.2	-3.90	-30.20
8	Gajpura	3	4.3	-1.30	10.4	-6.10	-7.40
9	Gajpura	1	15.3	-14.30	20	-4.70	-19.00
10	Kapariokakhera	2	11	-9.00	12.7	-1.70	-10.70
11	Kapariokakhera	3	12	-9.00	18	-6.00	-15.00
12	Nagaliya	6	9	-3.00	15	-6.00	-9.00
13	Nagaliya	7	9	-2.00	15.5	-6.50	-8.50
14	Phoosariya	5	16.8	-11.80	19.3	-2.50	-14.30
15	Phoosariya	4	18.5	-14.50	18.5	0.00	-14.50
16	Patiya	12	22	-10.00	25	-3.00	-13.00
17	Patiya	12	30	-18.00	31.1	-1.10	-19.10
18	Rayala	4	9	-5.00	16	-7.00	-12.00
19	Rayala	5	12	-7.00	14.4	-2.40	-9.40
	Average	**6.05**	**15.61**	**-9.56**	**19.85**	**-4.24**	**-13.80**

Wells and Irrigation

The open dug wells are the major source of irrigation. The irrigated land forms a very minor part of the total land in the area. The wells generally have less than 1 hectare command area, this due to the fact that the yield of wells is low ranging from 40,000 litres to 50,000 litres per day only.

Table 7 irrigated land and wells

S. No	Village	Total agriculture land (ha)	Rainfed land (ha)	Irrigated land (ha)	Total wells for irrigation	irrigation command of wells (ha)
1	Beripura	16	10	6	6	1
2	Bhopakheda	210	155	55	37	1.49
3	Dhawadia	128	98	30	41	0.73
4	Gajpura	20	14	6	9	0.67
5	Kapariokakheda	34	22	12	23	0.52
6	Kheraphala	49	33	16	16	1.00
7	Nagaliya	97	79	18	41	0.44
8	Paitya	24	14	10	12	0.83
9	Phoosariya	129	107	22	40	0.55
10	Rayla	53	33	20	23	0.87
	Total	**760**	**565**	**195**	**248**	**average = 0.81**

The pumping from wells is generally done using submersible motors from 2 HP to 3 HP capacities that run on single phase electric supply. There are some shallow bore wells in the area which are operated through 3 phase electric supply, but these are less in number and their depth generally range from 110 meters to 150 meters below ground level. There is a practice of sharing irrigation water from single well by many partners which may be of 5 to 6 members. The water is taken by each partner on the rotation basis during Rabi crop irrigation and the cost of pumping is shared by the partners.

The agriculture land is located at different elevations, since the area is undulating, therefore wherever the fields are on higher elevations the water is lifted from the wells that are located in the valley or along stream courses, through the plastic pipes although the head increases by 30 to 40 meters, but the availability of water for irrigation is ensured. The water is sometimes transported even up to 1500 to 2000 meters from wells to agriculture fields. It is a cumbersome exercise for the farmers during irrigation season but there is no alternate system is available like lift irrigation schemes or overhead tanks from where water can be distributed to fields.

Drinking Water

The drinking water is obtained from both open dug wells and hand pumps. The hand pumps have been constructed in all the villages and serve as a good hygienic drinking water source. The depth of pumps is generally 60 meters and usually these supply water in summer months. The drinking water from shallow dug wells may have biogenic contamination. The chemical quality of groundwater is however potable and there no harmful constituents like fluoride, nitrates or heavy metals etc.

Table 8 Details of hand pumps

S. No	Name of village	Total no of hand pumps	Functional hand pumps	Defunct Hand pumps	Average depth	Water availability months	HH benefited
1	Beripura	4	3	1	50	12	20
2	Bhopakheda	7	3	4	60	12	15
3	Dhawadia	60	30	30	50	12	40
4	Gajpura	5	5	0	60	12	10
5	Kapariokakhera	4	4	0	60	10	8
6	Kheraphala	3	2	1	50	12	20
7	Nagaliya	25	3	22	60	12	30
8	Patiya	3	3	0	60	12	10
9	Phoosariya	13	13	0	60	12	50
10	Rayla	7	7	0	60	12	40
	Total	**131**	**73**	**58**			**243**

Chapter 5

Hydrological conditions, Climatic variability and impacts

Rainfall Variability

The project area lies within semi-arid region with variable climatic conditions. The analysis of rainfall pattern of the area for period of 34 years (1980-2013) indicates that wet and dry cycles reoccur alternately after 4 to 5 years. Although the average rainfall is 613 mm but it is seen that there are 32 per cent and 3 per cent deficit and scanty rainfall and 9 per cent and 12 per cent rainfall is under excess and abnormal category respectively. The impact of rainfall in the area is very significant on the agriculture and water resources. The maximum cultivable area is under rain fed crops mainly comprising of maize and pulses. The maize is a staple food for the habitats of the area and is dominantly grown for food security. The extreme conditions of rainfall effects the maize crop production and consequently create food shortage for the households. Low and erratic rainfall hampers maize production due to non-availability of sufficient soil moisture for the growth of crops. Delay in monsoon also causes a great concern to farmer and sometimes early sowing after pre monsoon shower also damages the crop if monsoon rains do not follow within 8 to 10 days. In case of heavy downpour or increased frequency of rainfall the crop is subjected to suffer because of water logged soil conditions. The floods cause severe soil erosion from the sloping areas which are major areas for rain fed crops. The excessive rainfall and temperature variation cause outbreak of pests also.

Surface Water resources

The surface water resources are not only limited in number but their capacity to hold water is also inadequate. The evaporation rate in the region is significant and has been estimated as 1.5 to 2 meters annually; under these circumstances surface water bodies are vulnerable to climatic variability. There are only 6 Ponds and 14 water harvesting structures (anicuts) in 10 project villages .In most of these ,water is accessible only for 3 to 5 months in a year, still these are important source for drinking water for the livestock of the area. The low rainfall does not fill up the water bodies sufficiently, therefore water scarcity for the livestock becomes apparent and alternate arrangements become necessary. The heavy rainfall or flood conditions may cause damage to the water bodies and siltation resulting in depletion in storage capacity of these structures and deterioration of quality of water.

Groundwater

Groundwater is the major source of water for agriculture and drinking purposes. The groundwater occurs under three major constraints viz, low recharge, restricted porosity and permeability of aquifers, and significant fluctuation of water table. The terrain is undulating and hilly therefore, runoff generation from monsoon is high and very soon water flows out of the area consequently recharge is very limited. The wells which are located along stream courses are however recharged from the stream flows and water levels rise immediately, whereas in hilly region wells are recharged at much lower pace and rise in water table is also slow. The Pre

Aravalli metamorphic rocks are endowed with only limited fractures and joints or contact planes wherein groundwater is stored thus making these aquifers oflow yield potential i.e. specific yield is only 1.5 per cent. The water table in the area varies considerably depending upon the geomorphic locations. The fluctuation in water table in different seasons is noteworthy, average depletion from post monsoon to summer season is more than 13 meters. The water levels in the wells decline immediately after irrigation of Rabi crops and reach to the maximum level in the wells up to summer season.

The groundwater occurs under unconfined conditions and corresponds directly to rainfall conditions. During low rainfall events aquifers are not recharged sufficiently to accomplish Rabi irrigation consequently result in low production of crops and poses a problem for drinking water in summer season. The irrigation command of the wells is less than 1 hectare as such if the groundwater is insufficient the irrigation command considerably reduces limiting the sowing area and crop production.

Most of the wells are shallow in depth and recuperation takes place after 24 hours to 48 hours, therefore sustainable yield from wells is not obtainable. The wells are generally shared by 4 to 6 farmers for irrigating their fields therefore over exploitation of groundwater is carried out resulting in depletion of water levels.

The open dug wells in the area are generally unlined and most of the wells are located along the stream courses. The heavy downpour during monsoon and inundation of streams causes threat to these open wells, these wells collapse or filled with silt and debris by the flood water and quality of groundwater also deteriorates. The wells become defunct and it takes time and money to renovate and make them operational.

There are 413 wells in the area and out of this only 248 wells are operational and even in these wells many are unlined and vulnerable to damage due to floods and contamination of aquifers.The climatic variability and its impact on hydrological resources in the area may be summarized as follows:

Table 9 Hydrological resources and impacts of climatic variability

		Climatic variability	
1	Rainfall	Low and erratic rainfall	Excessive or abnormal rainfall
		Delay in sowing, loss of seeds, crop failure or meager production may cause threat to food security, pasture land degradation	Water logging in soil, soil erosion, low production or failure of crops, inability to cultivate the land and threats of pests Unpredictable rains due to Western disturbances during harvest time may cause unusual loss to crops.
2	Surface water	Insufficient water storage available for livestock and human population	Damage to Water harvesting structures and ponds,silting and contamination in water.
3	Groundwater	Insufficient recharge, inadequate water for Rabi irrigation, depletion of water table, delayed recuperation in the wells	Unlined wells may collapse, silting and debris filling, contamination of aquifers, loss of pumping equipments delivery pipes etc.

Chapter 6

Climate resilience and adaptive measures

Climate resilience can be generally defined as the capacity for a socio-ecological system to absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system.

The climatic variability and largely climate change impacts are necessary to address for sustainable growth and ensured agriculture based livelihood. It is important to generate awareness amongst farmers and local people through comprehensive technical inputs that are necessary for farming decisions.Renovation and construction of water resources for sustainable supply of water for irrigation and drinking water for human and livestock population must be taken on priority with the help of local Panchayats and other organizations. Some of the important measures for different hydrological resources are outlined below:

Table 10 Hydrological resources and important measures

Rainfall variability	Access to Weather information is important- Mini Agromet observatory is very useful for farming decisions, sowing time and to know threats of pests and possibility of heavy downpours.
Surface water	The water harvesting structures, tanks and ponds are very essential for storage of monsoon runoff. Depending upon water budget of the watershed more WHS may be constructed and desilting and renovation of existing structures must be taken up to increase capacity. Plantation along water structures is useful to reduce evaporation from the water bodies.
Groundwater	Groundwater recharge structures are very useful to build up groundwater storages. The open dug wells must be lined and deepen sufficiently to tap maximum thickness of aquifers. The recharge pits near wells, hand pumps and bore wells must be constructed and sub surface barriers along stream courses at suitable locations are necessary for sustainable yield from wells

Sum up

The adaptive measures for improving water availability are generally site specific depending upon local geomorphic and hydrological conditions of the area. There are many proven practices for water harvesting, water conservation and water recharge. In some of the water stressed areas with small technical inputs and support of local farmers water availability has been significantly improved. The best practices adopted by farmers in different areas are important to study and may be tried with appropriate modifications.

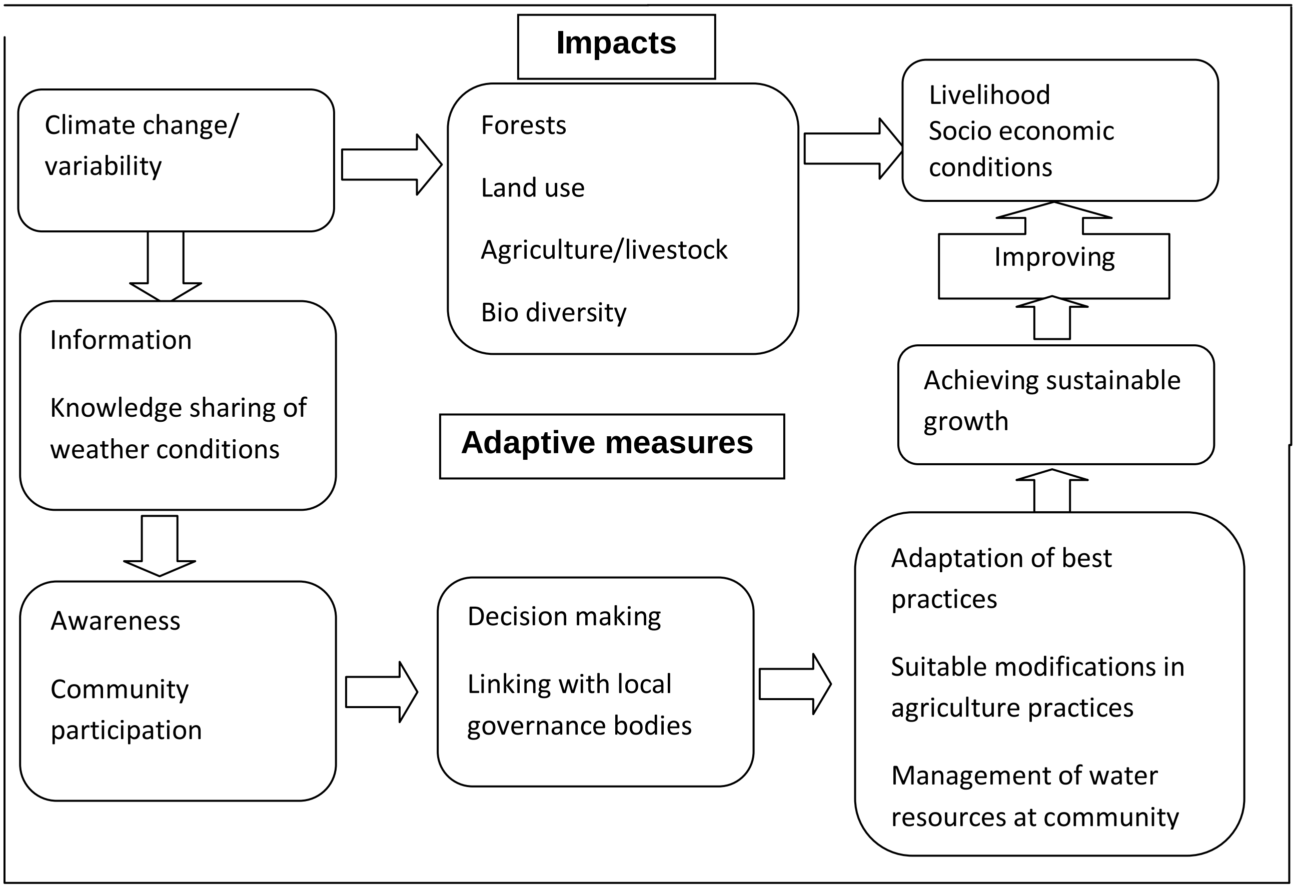


Fig 9 impacts and adaptive measures

Chapter 7

Conclusions and way forward

The hydrological appraisal of the project villages have revealed following salient features of the area:

- The area is covered under semi-arid climatic conditions wherein rainfall pattern is variable and erratic, delay in monsoon, varying number of rainy days and duration and intensity of rainfall varies significantly. Many a times western disturbances result in untimely downpours and cause damage to the crops.
- The villages are located in hilly and undulating terrain where mostly streamlets of first and second order mark the drainage and high runoff is generated during rainfall. The third order streams lies in the valley portion.
- The landforms are of typically hilly type with limited cultivable land, rain fed cultivation dominates and very little land is covered under irrigation.
- There is no major water body in the area like irrigation dam or big tank or pond, however small water bodies like water harvesting structures and small ponds with limited capacity exist in some villages. The water scarcity or abundance is totally dependent upon monsoon rainfall and therefore these are vulnerable due to variable and erratic trend of rainfall.
- The groundwater is the major source of irrigation. Open dug wells are used for irrigation; these are generally located along stream courses. The aquifers comprise of hard crystalline metamorphic rocks with very limited porosity and permeability consequently have inadequate storage capacity.
- The wells are of shallow depth and mostly unlined and without proper parapet walls. The depth to water declines after monsoon and after Rabi irrigation water levels depletes considerably leaving very little amount of water during summer season.
- The yield of wells is not sustainable; the wells are shared by group of farmers for irrigating their fields. The water is lifted up to far off fields at higher elevations, thus the head is increased causing reduction in discharge at the outlet.

- The drinking water is obtained through shallow hand pumps but these cater limited population and in summer a number of hand pumps are dried up or remain with meager water due to depletion in water levels.
- The land forms and land use pattern of the area along with the hydrological conditions reveal vulnerable situation for the livelihood of the people. ***A serious attention is needed to work out suitable measures for improving the water management conditions for adapting to the variable climatic conditions.***

Way forward

It is important to build up the capacity of socio-environmental system to absorb the climatic stresses and reorganize water availability and consumption processes through area specific interventions involving local community and local bodies. Some of the necessary actions may be taken up as follows:

1. Set up of mini agro-met lab and capacity building of the farmers for weather based farming decisions.
2. There is abundant waste land (Govt. waste land 30% and private 32%), wherein soil water conservation measures must be taken up for improving soil moisture and infiltration of rainwater.
3. Improvement of existing surface water bodies by improvement in the catchment area and increasing the capacity by de silting.
4. Water harvesting can be enhanced at the local level through proper scientific inputs for planning of these interventions. These inputs include: analysis of rainfall intensity and pattern; reliable estimates of runoff from the catchments; analysis of engineering properties of the soils; topography; and, geo-hydrological data including geo-hydrological parameters of the formations, mapping of geological structures & groundwater surface water .
5. The improvement of open dug wells is very necessary. The wells are generally unlined and without parapet walls, therefore vulnerable during floods as the quality of water is derogated as well these may collapse. The farmers may be involved in participatory mode to improve the open wells. This activity may be taken through MANREGA at Panchayat level also.
6. Although there are some bore wells in the area but construction of bore wells should not be encouraged due to the fact that the area do not have potential aquifers in deeper

horizons and there is always a risk of going failure which would cause disappointment and financial loss to the farmer.

7. Under the existing hydro-geological set up of the area, it is feasible to increase the water storage capacity of open wells through deepening of wells by simply adopting the recommendations of Groundwater Department of Rajasthan. The recommendations for the villages of project area falling in Bhinder block is that the dimension of wells should be 3 meters X 5 meters right up to bottom and the depth should 15 to 20 meters below ground level. Even if 3 to 5 meters deepening of wells is done the yield of wells may improve by 4000 to 6000 litres per day.
8. The groundwater in the wells comes through cracks, fractures or joints; these are however clogged due to silting and crystallization of calcium (in some cases). The openings in the well sections is necessary to clean and widen through either by compressed air or if possible by lateral boring. This would increase the inflow of groundwater in to the wells and improve the recuperation.
9. The sub surface barriers across the nala sections are very useful in recharging the wells located along these stream courses. Appropriate locations can be marked for construction of sub surface barriers using local materials comprising of clay and boulders and pebbles.
10. The farmers may be encouraged to construction of irrigation storage tanks at higher elevations, wherein water can be pumped from wells and field irrigation can be done by gravity flow through plastic pipes. This would provide time to recharge the wells for next pumping session and reduce the head loss at the same time save the energy also.

XXX - XXX

Annexure-1- Well inventory details										
Name of Villages	Well type	Year of constructed	Coordinates		Elevation from MSL (m)	Total depth of well (m)	Depth to water in Dec (m)	Diameter (m)	Depth to water in monsoon (m)	Depth to water in summer (m)
Beripura	Unlined	before 20 years	N 24°32.662'	E074°05.220'	473	8.3	6.8	3.15	6	8.3
Beripura	Unlined	before 25 years	N 24°32.722'	E074°05.205'	477	12.2	11.7	4	0	12.2
Beripura	Unlined	before 18 years	N 24°32.619'	E074°05.229'	475	19.5	10	3.5	5	18
Beripura	Unlined	before 50 years	N 24°32.534'	E074°05.197'	474	15.2	8	5	5	12.2
BhopaKheda	Unlined	before 80 years	N 24°32.775'	E074°05.718'	497	23.5	20.5	4.1	10	23.2
BhopaKheda	Lined	before 100 years	N 24°32.647'	E074°06.840'	498	30.7	28.4	4.5	11	30.35
BhopaKheda	Lined	before 54 years	N 24°32.528'	E074°06.676'	498	36	23.7	4	10	35
BhopaKheda	Unlined	before 40 years	N 24°32.544'	E074°06.684'	496	34.7	30.3	4.2	4	34.2

Name of Villages	Well type	Year of constructed	Coordinates	Elevation from MSL (m)	Total depth of well (m)	Depth to water in Dec (m)	Diameter (m)	Depth to water in monsoon (m)	Depth to water in summer (m)	Name of Villages
Gajpura	Lined	before 100 years	N 24°32.855'	E074°05.517'	474	12.4	4.3	5	3	10.4
Gajpura	Unlined	before 65 years	N 24°32.717'	E074°05.281'	470	21.5	15.3	6	1	20
Kaparioka Kheda	Unlined	before 50 years	N 24°32.564'	E074°04.791'	461	13	11	3.4	2	12.7
Kaparioka Kheda	Unlined	before 50 years	N 24°32.587'	E074°04.860'	465	18	12	5	3	18
Nagaliya	Unlined	0	N 24°31.304'	E074°04.177'	462	15	9	4.5	6	15
Nagaliya	Unlined	before 30 yrs	N 24°31.263'	E074°04.165'	461	15.5	9	3.3	7	15.5
Phoosariya	Unlined	before 50 yrs	N 24°33.086'	E074°05.667'	488	19.3	16.8	3.5	5	19.3
Phoosariya	Unlined	before 54 yrs	N 24°33.005'	E074°05.806'	486	18.5	18.5	4.5	4	18.5
Patiya	Lined	before 25 yrs	N 24°33.427'	E074°05.335'	496	25	22	3.5	12	25
Patiya	Unlined	before 15 yrs	N 24°33.360'	E074°05.480'	488	31.1	30	4	12	31.1
Rayla	Unlined	before 35 yrs	N 24°32.035'	E074°04.805'	458	16	9	6	4	16
Rayla	Unlined	before 30 yrs	N 24°32.310'	E074°05.066'	462	15	12	5.5	5	14.4