Scientific contribution
No: INCOH/SAR-29/2007

STATE OF ART REPORT

FLOOD OF AUGUST 2006 IN ARID RAJASTHAN :
CAUSES, MAGNITUDE AND STRATEGIES

RETIRED ICAR EMPLOYEES WELFARE SOCIETY (RICAREWES), JODHPUR

Publication of
Indian National Committee on Hydrology (INCOH)
(IHP National Committee of India for UNESCO)
National Institute of Hydrology, Roorkee - 247 667
INDIA

INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)

(IHP National Committee of India for UNESCO)

Constituted by Ministry of Water Resources in 1982

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Editors: A.S. Faroda and D.C.Joshi

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INDIAN NATIONAL COMMITTEE ON HYDROLOGY(INCOH)
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PREAMBLE

Floods in the desert are not common. Compared to the other part of country, floods in desert may be of low magnitude but these are more devastating because people and the ecosystem are not prepared to receive sudden torrential down pour. In Thar during 1901 to 97 there were 25 instances of heavy rainfall out of which severe and wide spread floods, occurred 7 times. Most of these floods occurred in Luni basin which has integrated drainage network and flood water found in the sense that the area does not have integrated drainage and therefore there is no outlet for flood water and litho logy and terrain conditions do not allow flood water to seep down. During the year 2006 Bar mar area received 750 mm rainfall against the men annual rainfall of 277 mm. Most of this rain occurred within a short span of time(19-22 August) Which resulted in flooding of low lying area near Kawas , Uttarai and malba villages. This caused heavy loss of human and animal life, disruption of mining infra structure, rail and road transport and degradation of agricultural lands. Despite all dewatering efforts water remained standing in the area and even after 300 days situation is grim.

The Retired ICAR Employees Welfare Society (RICARWES) organized a seminar on "Flood of August 2006 in Arid Rajasthan: Causes, Magnitude and Strategies " on 15th December 2006 with the financial support of Indian National Committee on Hydrology (INCOH), Roorkee. In this seminar Scientists of related research Institutes and organizations participated and presented papers on causes, magnitude and strategies both short and long term to combat the inundated areas and gainfully utilize the pounded water. The papers have been compiled and edited in the form of book. I congratulate the RICARWES and the editors for timely publication of the book. The books a scientific record of the event and will be useful for all those interested in desert floods and particularly to administrators to adopt long term measures, so that life and natural resources can be protected during future fury.

24/10

(K D Sharma)

PREFACE

Floods always make news and more so when arid region experience flood. The flood of August 2006 in arid Rajasthan had been devastating causing heavy loss of human and livestocks life, loss of agricultural land, and disruption of mining activities which were major source of livelihood for the local people. Efforts to drain out or percolate water did not succeed and area of Kawas and Malba villages remained under 10-20 feet deep water for months together and rail transport was cutoff.. This flood was unique, because the earlier floods received in the Thar in years 1979 and 1990 were restricted to Luni basin which has integrated drainage basin and flood water could drain out.

Realizing the gravity of situation the Retired ICAR Employees Welfare Society (RICAREWES) Jodhpur organized a seminar on "Flood of August 2006 in Arid Rajasthan: Causes, Magnitude and Strategies" with the financial support of Indian National Committee on Hydrology (INCOH), Roorkee on 15th December, 2006. Eminent Scientists participated in the seminar and presented papers on various aspects of flood. including monsoon scenario of August, 2006, lithology and terrain characteristics of the area, impact of flood on agriculture, livestock and wild life and suggested short and long term preventive measures, efficient utilization of flood water and proposed drainage route for the pounded flood water. The information will be very useful for planning flood prevention in future.

The papers presented have been edited in the form of book and it is hoped that the the compendium will be very useful for all those concerned with the floods in the Thar desert. The organizers take this opportunity to express sincere thanks to Dr. K. D. Sharma, President INCOH, Roorkee for financial support for organizing the seminar, Dr. Pratap Narain, Dirctor, CAZRI, Jodhpur for infrastructure support and to Dr. L.S. Rathore, Head, Division of Medium Range Weather Fore cast, Ministry of Earth Resources, New Delhi for delivering key note address and to all the participants for their contributions.

A. S. Faroda
D.C. Joshi
Editors

Contents

Monsoon-2006: Scenario Over Rajasthan

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There is a popular saying in western Rajasthan: *Jaankhiyon laare meh*. Loosely translated, it means a good rain always follows dust storms. This summer when Rajasthan's Jaisalmer and Barmer districts witnessed dust storms, people thought it augured relief after six years of drought. The rains did come but the boon fast became a bane. Barmer was deluged with 750 mm of rainfall in the last week of August: five times the district's average annual rainfall. Floods also ravaged arid Gujarat, and neighbouring Maharashtra, while usually-wet Assam reeled under droughts.

Barmer received 720 mm of rainfall in 1990 and in 1994, 600 mm rain fell over the district. Such inordinate rainfall was spread over a year. This time, the downpour was a weeklong affair and was compounded by rainwater flow from neighbouring Jaisalmer. Elderly people in Barmer say that rainwater took the drainage route of rivers that once passed through Rohali and Nimbala villages. They say "These now-extinct rivers originated in the Jinjhiniali region of Jaisalmer district, merged in Luni River before entering Barmer, and finally disappeared into the Rann of Kachchh in Gujarat,". The villagers maintain water gushing down the Rohili-Nimbala route drowned Kawas town and villages *en route*. Rainwater from Jaisalmer also took the drainage path of the extinct rivers, Lik and Sheepasaria. Water that came along this path caused havoc in Malwa village.

Some Facts

About 57.98 lakh population, 17.35 lakh hectares of cultivable land in 5809 villages of 12 districts were severely affected. Twelve districts faced the worst ever kind of flood and torrential rains included Banswara, Barmer, Chittorgarh, Kota, Dungarpur, Jhalawar, Jalore, Pali, Rajsamand, Sirohi, Udaipur, and Jaisalmer. Malba, Kawas and Bhadaka villages were still marooned in Barmer district though the people were evacuated with the help of helicopters but the water level was recorded at 20-25 feet, these villages were located on the top of big sand dunes. Heavy rain/flood claimed about 85 lives; with 50 in Barmer, 10 in Pali, 6 in Udaipur, 4 each in Jalore and Rajsamand, 3 each in Chittorgarh and Sirohi, 2 each in Dungarpur and Banswara and 1 in Jhalawar.

Weather system formed during 2006

The progress of monsoon during 2006 has been presented in **Fig. 1**. A total of 16 systems formed during the season (Table 1). All the systems formed over Bay of Bengal except one severe cyclonic storm formed over Arabian Sea and one land depression. Most of the systems moved in West north westerly (WNW ly) direction from Bay towards Gujarat and adjoining Rajasthan region. Although it arrived 4 days in advance on Kerala coast there was very little progress in June, and it reached the margin of western Rajasthan by 30 June. In the Barmer area it reached by 20th July. Rainfall over Barmer was 750 mm in the last week of August. In 1990 there was 720 mm rainfall and in 1994 it was 600 mm, but distributed over a longer period. Position of clouds as seen through INSAT on July 30, 31; August 1, 16, 17, 18, 19, 20 has been presented in **Fig. 2**

Table 1. Weather system formed during 2006

Low pressure areas (LOPAR)	DEP (Depression)	DEEP	DEP (Depression)	Cyclonic storm (CS) /SCS
June	1	-	-	-
July	3 +1 (WML)	1	-	-
August	1	3	1	-
September	1	3		1scs (ARB)
Total 16				

Synoptic Conditions responsible for deluge over Barmer

A depression lay over north Orissa on 16 August. It moved northwestwards to Chhattisgarh on 17th, moving west-north westerly (WNWly) weakened into a WML and lay over southeast Rajasthan and adjoining west Madhya Pradesh in the morning of 19August. It lay as a low pressure areas (LOPAR) over west Rajasthan and neighbourhood during 20-22 August and over south east (SE) Pakistan and adjoining southwest Rajasthan on 23 August. Weekly rainfall scenerio of Rajasthan and departure (%) from normal is presented in Table 2 and **Fig. 3.** Fairly widespread rainfall with isolated/ scattered heavy to very heavy falls occurred over Gujarat region and Rajasthan and active/ vigorous monsoon caused 367% above normal rain over west Rajasthan and 67% above over east Rajasthan during 17-23 August 06. Weekly cumulative rainfall (% departure) for different districts of Rajasthan where rainfall occurred in excess during August 06 on weeks ending 2nd, 9th, 16th, 23rd, and 30th August are presented in **Fig.4**. The data reveals that in Barmer and Jaisalmer districts up to 16th August increase in cumulative rainfall was less than 50% where as in other districts the values of increase in cumulative rainfall right from 2nd August was more than 50 %.

Maximum Rainfall vs. Previous Records

At some of the raingauge stations spread over Rajasthan, comparison between maximum rainfall received during monsoon 2006 with maximum rainfall received during a single day in previous years (Table 3) revealed that at all the stations much higher rainfall had been recorded during previous years also.

Table 2. Rainfall scenario of Rajasthan: Weekly rainfall departure (%) from normal

Week	East Rajasthan	West Rajasthan
1-7 June 2006	+359	-1
8-14 June 2006	-97	-67
15-21 June 2006	-85	-52
22-28 June 2006	-44	-7
29 June – 5 July 2006	-15	-6
6 –12 July 2006	-17	-30
13-19 July 2006	-85	-95
20-26 July 2006	+26	-27
27 July – 2 August 06	+141	+ 79
3-9 August 2006	-14	+91
10-16 August 2006	+96	+44
17-23 August 2006	+64	+367
24-30 August 2006	-91	-79
31 August- 6 September 06	+41	-14
7-13 September 2006	-35	-3
14-20 September 2006	-78	-95
21-27 September 2006	-43	+45

Table 3. Maximum rainfall vs. previous records at different stations

Station	Maximum rainfall during one day in monsoon 2006		Highest rain previous record	
	Rainfall (mm)	Day of rain 06	Rainfall (mm)	Day of rain
Rawatbhata	113.0	28 July	303	30 July 1982
Banswara	137.8	21 July	273.4	31 July 1991
Mount Abu	184.0	29 July	460	5 July 1943
Kota	100.2	15 August	179.7	31 August 1978
Banswara	123.2	19 August	371.2	26 August. 1987
Chittorgarh	123.0	1 August	144.2	7 August 1979
Dabok Air.Port	142.0	19 August	136.5	1 August 1968
Udaipur city	141.0	1 August	135.5	28 August 1965
Barmer	162.0	22 August	255.5	5 August 1944
Jaisalmer	136.4	21 August	204. 0	16 August 1973
Mount Abu	259.4	20 August	484.8	8 August 1941

Weather Forecast

Weather forecast issued one week in advance to Ministry of Agriculture has been presented in Table 4.

Summary and conclusion

- West Rajasthan showed skewed distribution of rainfall which is not good for growing crops. No records for heavy rainfall broken during Monsoon-2006.
- East Rajasthan rainfall were well distributed in time.
- Numerical weather prediction models are able to predict prolonged widespread rainfall on sub-divisional scale for week period during monsoon, reasonably.
- Weekly predictions for weeks ending on August 16 and August 23 of 2006 demonstrate the predictability in week period on sub-divisional and agro-climatic zone scales
- It was pointed out that meso-scale models are to be developed and run for west Rajasthan which will help better predict the weather. However, it requires a closer network of automatic weather stations, which should be recommended to the Government.
- Pattern of the system in eastern India is reverse to western India. Medium range weather forecast holds good for 25-30 km radius.
- National rainfed authority has been formed it is not known whether component of rainfall is included. It was suggested that a copy of this seminar may be sent to Ministry of Agriculture..
- Weather component of wind erosion up to 12 km height correlated with rainfall
- The prediction is based on sea surface temperature.
- For meso-scale modeling, Rajasthan is entirely different from rest of the country because there is large spatial and temporal variation. For this purpose meteorological stations should be strengthened.
- There is no perceptible increase in rainfall during last many years we have cyclic behaviour of drought. Is there cyclic behaviour of rains?

It was concluded that in western Rajasthan, the distribution of rainfall was skewed leading to its adverse impact on people and livestock. Compared to this the rainfall in East Rajasthan was better distributed. Numerical prediction system for such rainfall distribution needs to be improved so that villagers/ farmers could be given prior hints of the rainfall situations.

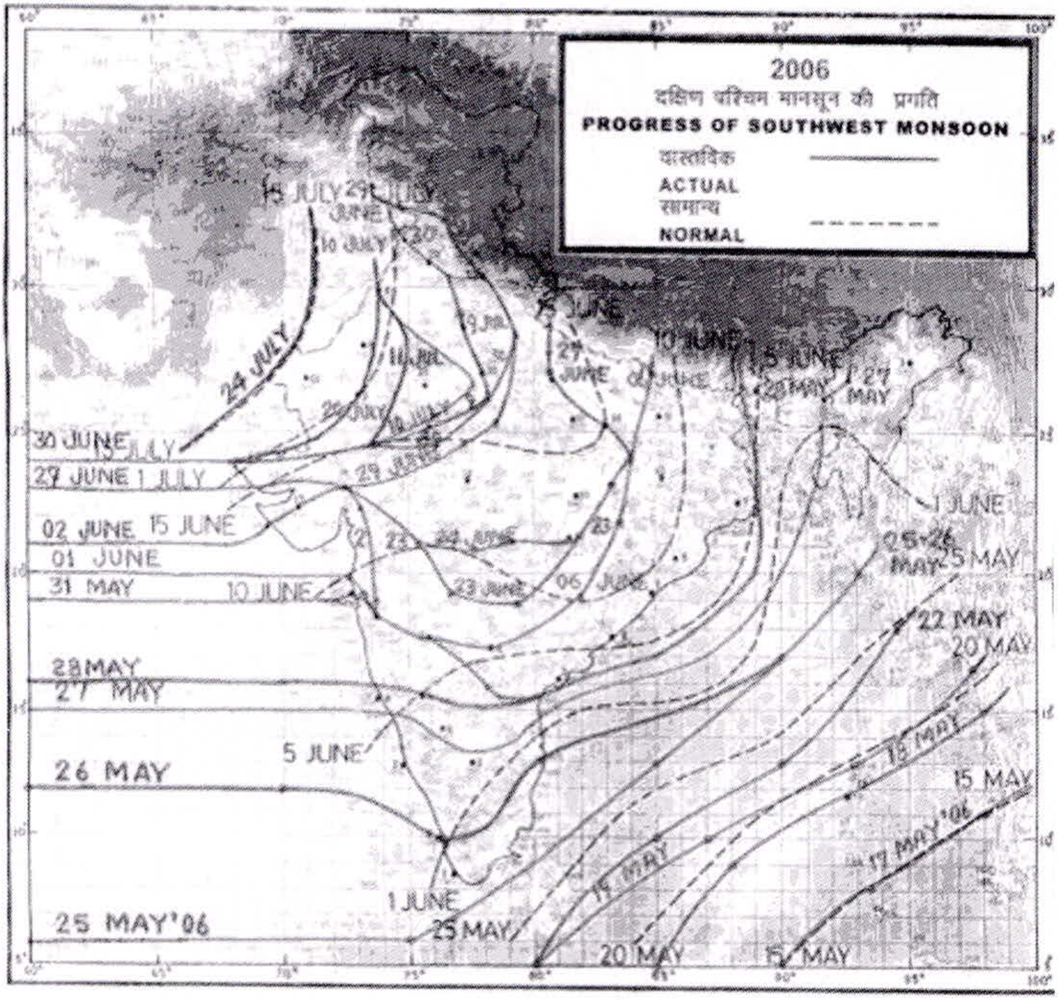
Table 4. Monsoon-2006: Weather Forecast (One week in advance) issued to Ministry of Agriculture, Government of India

Date of Forecast	Forecast for Next week	Verification based on IMD's reports	Agricultural advisory
5 June	•Weak monsoon current over Arabian Sea expected during next 4-5 days. •Consensus forecast from several numerical models suggests that SW monsoon likely to go into weak phase from 8 June, leading to overall decrease in rainfall activity over the country	•Monsoon remained weak till 11th June. •Most of the places of NW and Central India remained dry and hot.	In NW India farmers are advised to raise paddy nursery in J&K, H.P., Uttranchal, Punjab, Delhi by selecting varieties like K-39, Palam Dhan, Pant Dhan-12, PR-108 and Pusa Basmati-1 respectively
12 June	•Continuance of prevailing weak monsoon condition. •Dry weather and heat wave conditions are likely to continue over parts of Rajasthan, U.P. & M.P. Parts of Bihar, Jharkhand, Orissa and West Bengal may also face heat wave condition in later part of the week.	•Monsoon remained weak during 8-14 June, with all India rainfall 46% below normal and 32 subdivisions scanty(28)/ deficient(4). Weak monsoon situation prevailed during the period up to 19th June. Heat wave conditions continue to prevail over north Rajasthan. Day temperatures over rest of plains of NW India, UP and adjoining MP are prevailing between 42-44°C.	Farmers of the areas where monsoon has advanced but have received deficient to scanty rains so far, are advised to defer the sowing of Kharif crops until next spell of rains. In NW India farmers are advised to raise paddy nursery in J&K, H.P., Uttranchal, Punjab, Delhi by selecting varieties like K-39, Palam Dhan, Pant Dhan-12, PR-108 and Pusa Basmati-1 respectively. Due to prevailing hot weather condition, sufficient water should be kept standing in nursery to avoid iron deficiency. In Central India mainly dry weather is predicted for next 5-7 days, farmers of this region are advised to only prepare the fields for sowing paddy nursery and other Kharif crops.
19 June	Prevailing conditions of weak monsoon may continue during next 2-3 days. Thereafter, revival of monsoon is likely over south peninsula. However revival may not be classical type.	SW monsoon revived on 20th with increase in the rainfall activity over south peninsula and was in active phase.	Farmers of areas where poor or no rains have occurred so far, are advised to defer the sowing of Kharif crops until next spell of rains. Good monsoon conditions are likely to prevail over southern and NE parts of India. Farmers of these areas are advised to continue the Kharif crop.

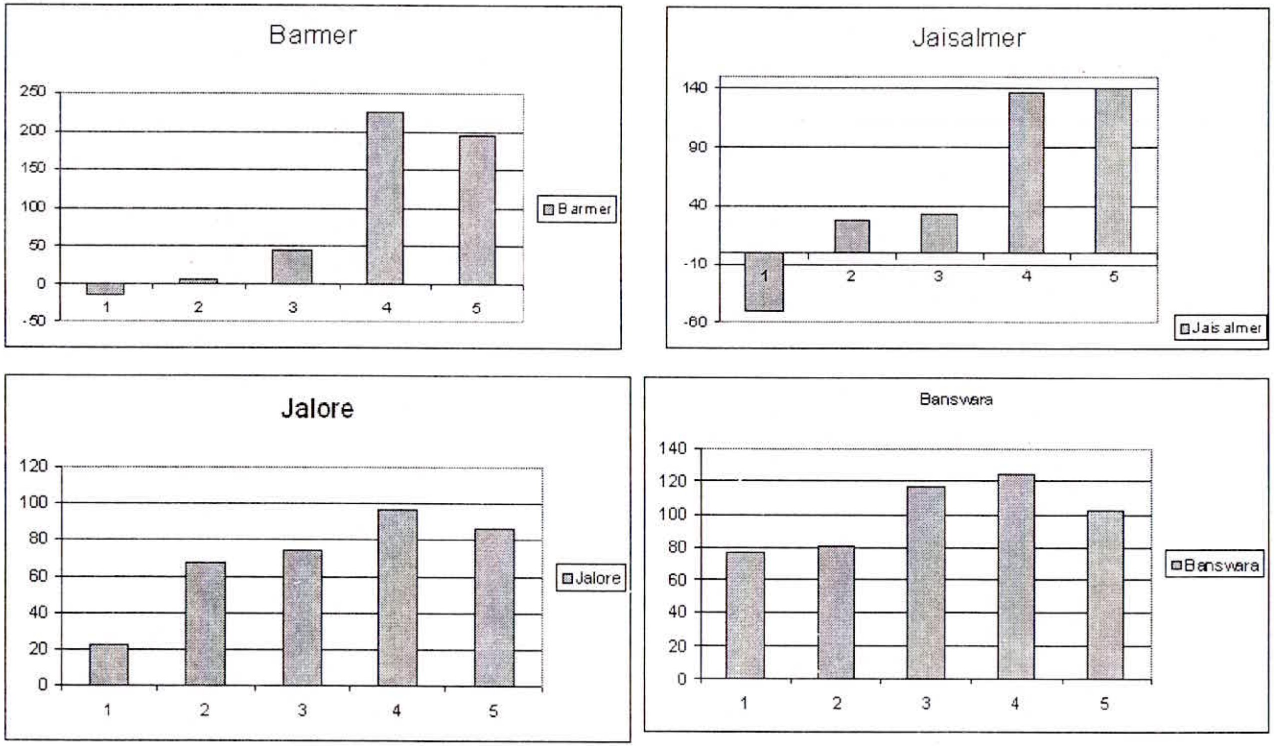
26 June	A CYCIR is likely to develop over west central Bay of Bengal around 29 June. It may intensify into a LOPAR and cause good rainfall activity over eastern part of the country. Conditions favourable for further advance of SW monsoon over remaining parts of Gujarat and Chhattisgarh; parts of East UP; Rajasthan and Madhya Pradesh during 3-4 days.	It covered most parts of Saurastra & Kutch and parts of Uttar Pradesh on 27 June. It further covered Gujarat and MP and some more parts of West UP, remaining parts of HP and some parts of Punjab and Haryana on 30 June	Farmers are advised to get ready for the sowing of Kharif crops as wide spread rainfalls are expected towards the end of the week in the Peninsular & Central region. In central India and eastern UP, Bihar, Jharkhand farmers are advised to raise medium and short duration varieties of paddy.
17 July	•LOPAR near Jharkhand and adjoining is likely to move slowly in a WNW direction. •Rainfall activity over West Madhya Pradesh, East Rajasthan, Konkan & Goa including Mumbai, Madhya Maharashtra and Gujarat is likely to increase during next 2-3 days . • A WD is likely to approach NW India around 21-22 July. It is likely to interact with monsoon flow. Under its influence rainfall activity may increase from 21st July over NW India.	•A CYCIR formed over Jharkhand & neighborhood on 19 July. It lay over Jharkhand and adjoining east UP and north Chhattisgarh on 21; Central part of MP and adjoining East Rajasthan on 23; and became less marked on 24 July.	In the light of rainfall forecast farmers are advised to take up transplanting of paddy seedlings in Eastern part of country and provide proper drainage in Maize fields. In NW India, Central India, A.P. and Maharastra advised for transplanting the nursery plants of vegetables like cauliflower, tomato, brinjal, chilli, etc. during this week.

24 July	•LOPAR present over NW M.P. & adjoining east Rajasthan on 23 July, is likely to move in NW direction and weaken further and merge with seasonal trough. •Monsoon trough is likely to be south of its normal position during next 2-3 days. Rainfall activities may be less over Indo-Gangetic plain, NE States and move over Central and Peninsula India. Another LOPAR likely to form over NW Bay of Bengal around 28 July. It may intensify further and rainfall activities may enhance over Orissa, West Bengal and Jharkhand.	•The monsoon covered entire country on 24 July. Monsoon trough was lying in its near normal position during the week. A LOPAR formed over NW Bay of Bengal off north Orissa coast on 27 July and concentrated into well marked low. It moved WNW ward across Orissa, Chattisgarh and NW M.P to SE Rajasthan and neighborhood on 1 August.	In the light of rainfall forecast farmers are advised to take up transplanting of paddy seedlings in Chhattisgarh,Vidarbha, east U.P., NE and NW India. In M.P., Konkan & Goa, Madhya Maharashtra, Gujarat and East Rajasthan farmers are advised to take up sowing of groundnut, soybean and pulses.
31 July	•Yesterday's well marked LOPAR over Jharkhand and adjoining areas of north Orissa and north Chhattisgarh is likely to move further in a WNW direction. Under its influence widespread rainfall with scattered heavy falls is likely to continue over Chhattisgarh and East MP during next 24 Hrs. Fairly widespread rainfall is also likely over north Telengana, Vidarbha and Jharkhand during next 2 days. Another low pressure is likely to form over NW Bay of Bengal in next 24-48 Hrs	•LOPAR over SE Rajasthan and neighborhood on 1 August, moved away in westward direction on 2 August and became unimportant. • Another well-marked LOPAR formed over NW Bay of Bengal on 1st August; intensified into depression and deep depression near Paradip. It moved westward across Orissa and Chattisgarh and lay over SW M.P on 6 August. • Monsoon trough remained in its normal and south normal position.	In Central India farmers are advised to complete the sowing of moong, urd, niger and early maturing rice varieties within this week in vacant fields. Farmers may sow paddy by lehi method in case of continuous rain. In Telengana region, taking advantage of rain, crops like castor, red gram and sunflower can be grown as contingent crop in unsown area of the region. For fast recovery of the crops, farmers are advised to go for top dressing in rainfed crop

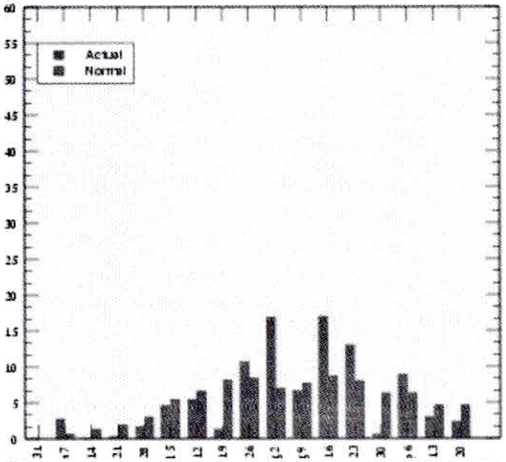
14 August	A well marked LOPAR over Chhattisgarh and neighborhood is likely to move in a WNW direction. Widespread rainfall with heavy to very heavy falls at a few places likely over south Chhattisgarh and Vidarbha. Heavy to very heavy falls at a few places over East M.P. and north Talangana; and isolated heavy falls over western parts of south Orissa during next 2-3 days. As the system moves WNW increase in rainfall activity is expected over West M.P., Marathwada, Madhya Maharashtra and Konkan & Goa in subsequent 3-4 days	•LOPAR moved in WNW direction across Orissa, Chhattisgarh, East M.P during 13-14th and over NW M.P. and adjoining east Rajasthan on 15th; over SW M.P. and adj. SE Raj. on 16th. Another fresh LOPAR over north Bay of Bengal off Orissa coast on 15; concentrated into a depression over NW BoB and lay centred at Balasore on 16th. The system moved in westward across north Orissa and Chhattisgarh. Moving WNWly, weakened into a well marked low pressure over SE Rajasthan and adjoining West M.P. in the morning of 19th. It weakened with heavy rains over causing flood in Barmer and Jaislmer districts.	Farmers are advised to provide adequate drainage in the fields of oilseed, pulse crops, sugarcane and cotton in the light of rainfall forecast. In those areas where rainfall has not been a excess farmers are advised to complete paddy transplantation vigorously. In certain areas of central, western and southern India. short duration pulses may be sown in the areas where traditionally sown crops could not be taken.
21 August	•LOPAR over west Rajasthan and neighborhood likely to move in NW direction. Fairly widespread rainfalls with isolated heavy falls are likely over Rajasthan and adjoining Gujarat region. Fairly widespread rainfall is also likely over Saurashtra & Kutch. •Another LOPAR lying over north Bay of Bengal off West Bengal-Bangladesh cost is likely to become more markedand move NWward.	•A LOPAR formed over north Bay of Bengal off West Bengal-Bangladesh coast on 20 August; became well marked on 22nd and lay over Jharkhand and neighborhood on 23 August as LOPAR. It moved westward and became less marked on 27 August and caused flood in parts of Rajasthan. •A CYCIR formed over NW Bay of Bengal Off Orissa and Gangetic West Bengal on 27 August.	As reduced rainfall activity is expected over most parts of central and west India for next 3-4 days, it is highly recommended to carry out intercultural operations in all types of crops at vegetative stage followed by fertilizer application. Punjab, Haryana, Uttar Pradesh and Bihar received deficient rainfall during previous week, farmers are advised to provide irrigation to paddy, maize, cotton field etc. Due to deficient monsoon rain for longer period in NE region, farmers are could not grow rice successfully.


2006
दक्षिण पश्चिम मानसून की प्रगति
PROGRESS OF SOUTHWEST MONSOON
वास्तविक
ACTUAL
सामान्य
NORMAL
24 JULY
30 JUNE
15 JULY
29 JUNE 1 JULY
02 JUNE 15 JUNE
01 JUNE
31 MAY
10 JUNE
28MAY
27 MAY
26 MAY
5 JUNE
1 JUNE
25 MAY'06
25 MAY
20 MAY
15 MAY
17 MAY'06
15 MAY
20 MAY
22 MAY
25 MAY
1 JUNE
10 JUNE
15 JUNE
27 MAY

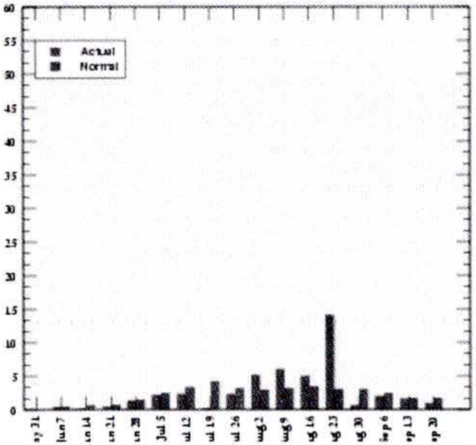
Weekly Cumulative Rainfall (% Departure) For Different Districts of Rajasthan Where Rainfall occurred in Excess During August 2006 (Weeks Ending on 2nd, 9th, 16th, 23rd 30 August)

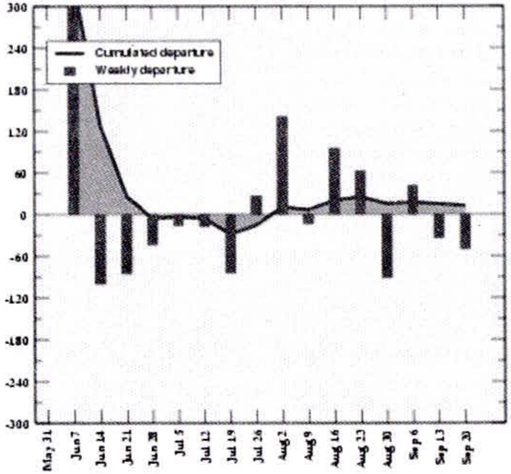


Monsoon-2006

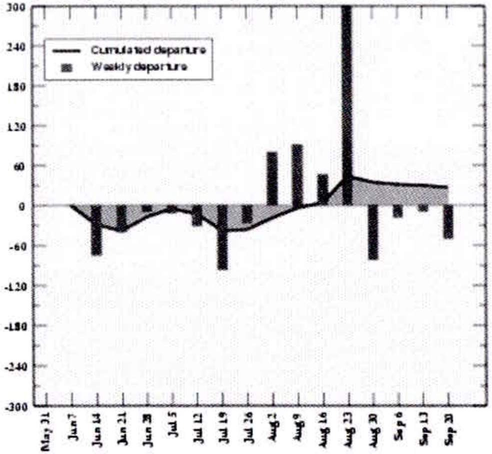


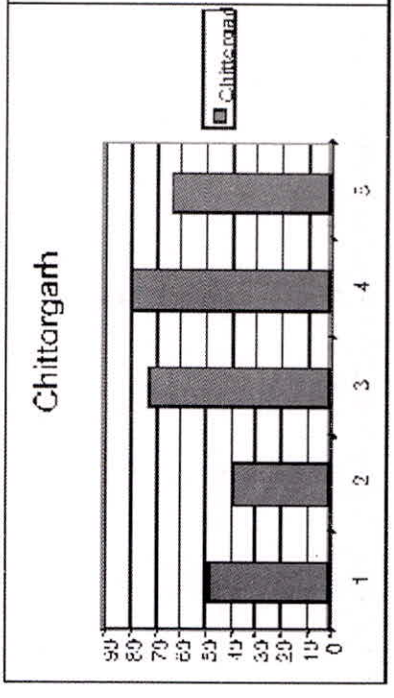
Weekly
Rain (mm)





Cumulative Seasonal & weekly Rainfall Departures (%)

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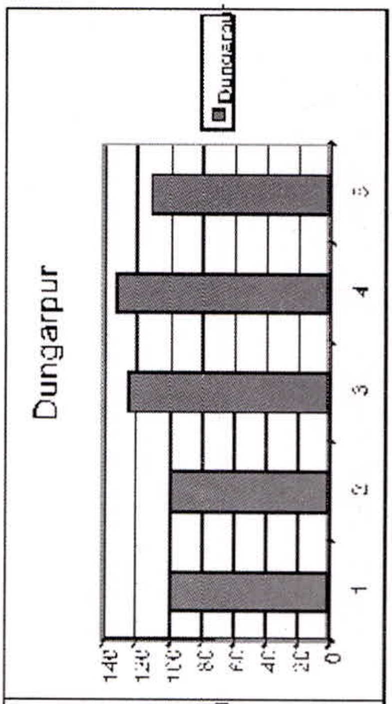
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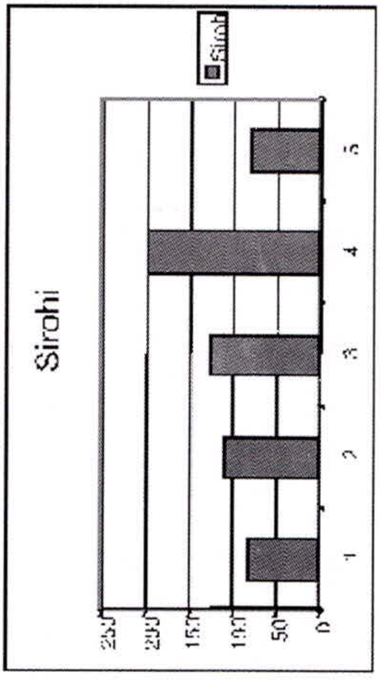
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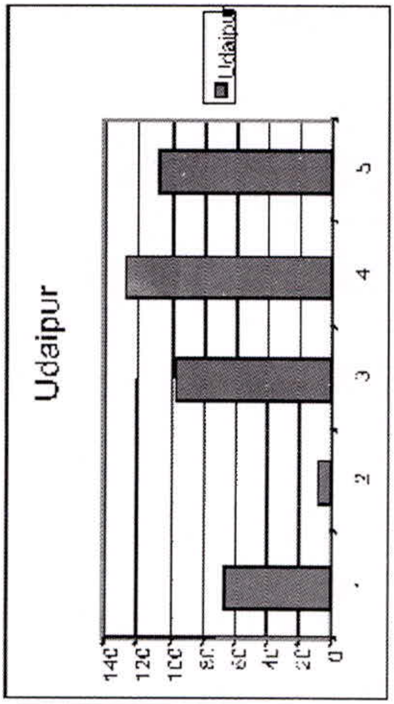
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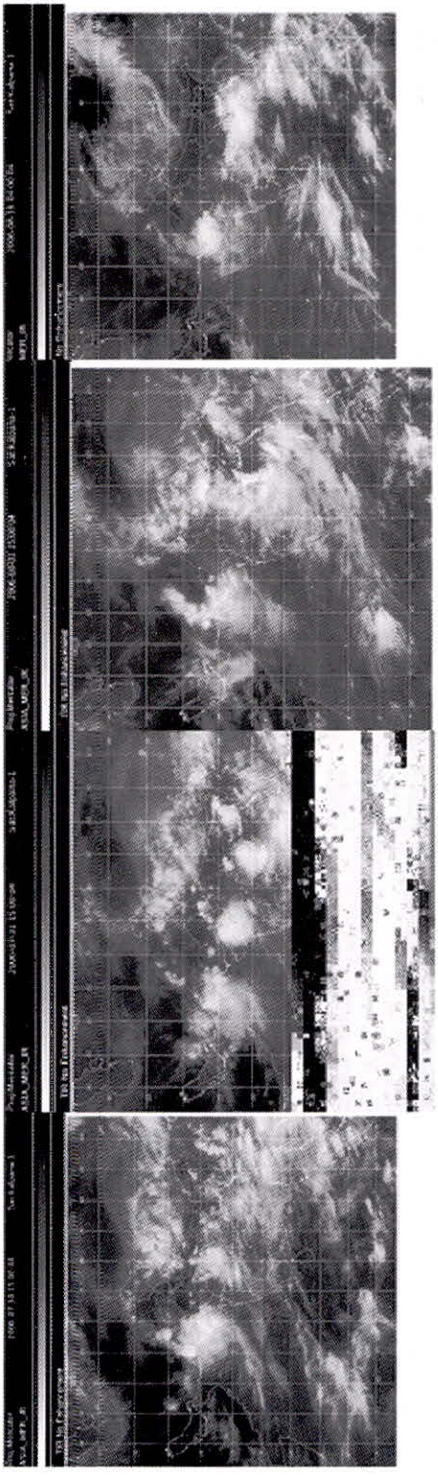

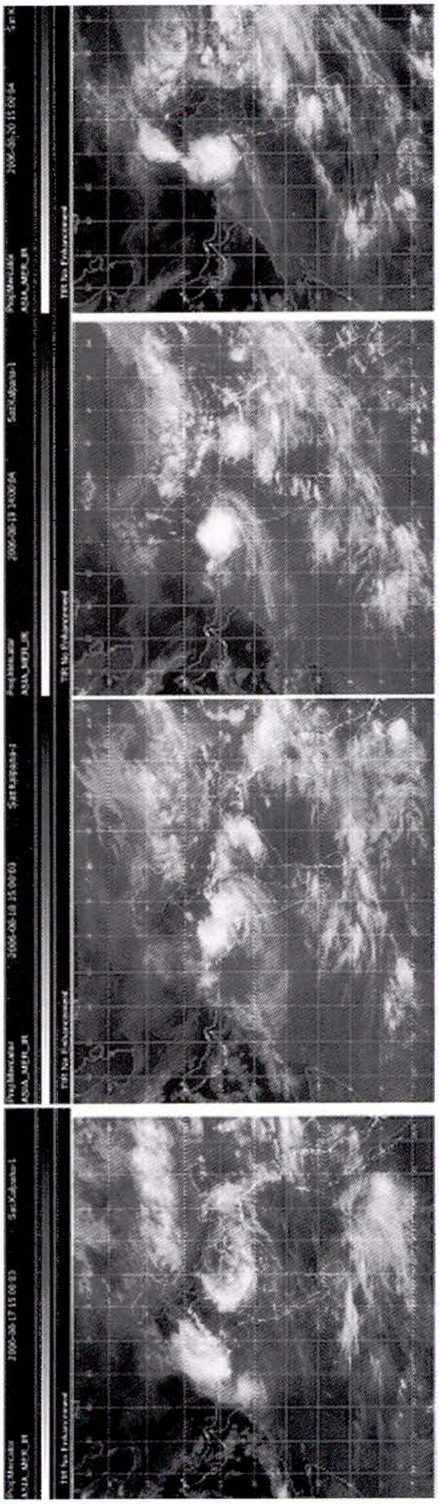

Floods in Barmer District (2006): Role of Geo-informatics Towards Rapid Action Plan Generation for Disaster Management

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Introduction

This year during the month of August 2006, Barmer and Jaisalmer districts received heavy, widespread and continuous rain for nearly one week particularly during August 20th to 23rd amounting to nearly 400 mm of rainfall in 4 days. Because of such heavy rains all water bodies got filled and ephemeral streams drained heavy run-off to the lower areas. As a result, the settlements, which were in lower areas (interdunal flats & depressions) got submerged resulting in heavy damage to human, livestock, property and infrastructure, particularly Kawas/Sar ka Par (with population of 1225), Malba (515) and Uttarlai (4188). Regional Remote Sensing Service Centre (RRSSC) Jodhpur carried out detailed analysis and investigation on this issue on war footing by understanding the gravity of situation under the ISRO's societal mission for disaster management support.

Role of Geo-informatics

The occurrence of flood in Barmer is a historic event as this area has not witnessed such loss to property, infrastructure, human and livestock population in recent past as gathered from different departments and media. Satellite Remote Sensing is the only available tool as on today to understand the entire flood phenomenon in near real time by viewing multi-date images (pre, during and post) for understanding and mapping of water spread areas, progress of water depletion, stream & channels of flood water flow, demarcation of catchment area, elevation, gradient, slope, depression areas, submerged settlements, damage assessment of infrastructure and agriculture lands, identification of safer sites for rehabilitation, optimal routes for draining out flood water from submerged villages, obstructing dunes along the drain path and destination of the drained flood water and finally the Environmental Impact Assessment. The analysis was a challenge due to desertic nature of the terrain and non-availability of well-demarcated drainage network and catchments with most of the organizations approached for database and outputs on current floods.

Data used

Following data sets were used in the analysis:

1. IRS LISS III, IRS AWiFS data
2. Radarsat SAR data
3. SRTM Digital Elevation data
4. Landsat ETM data
5. IKONOS data

6. Topomaps (Surveyed in 1928 – 30), published by US Army (1955)
7. SOI Toposheets surveyed in 1958-59 and 1983-84
8. Climate data
9. Digital archive data of RRSSC-J

Water spread area analysis

Water spread areas were analyzed using data on 24th August 2006 and 5th September 2006 for immediate rapid action plan generation. Total water spread in entire Barmer district was 244.51 sq. km, on 24th August, which reduced to 171.91 sq. km on 5th September 2006. Size wise distribution of water

Table 1. Size and number of water bodies in Barmer district as on September 5, 2006

S.No.	Size (ha)	Number
1	< 2	887
2	2 – 5	218
3	5 – 10	136
4	> 10	240
	Total	1481

Change analysis was carried out for Kawas, Malwa and Uttarlai water spread areas and status of water spread on two dates presented in Table 2 clearly indicate that there is marginal change in water spread areas at these three most affected sites.

Table 2: Water spread on 24th August and 5th September 2006

Places	Water spread area in sq km		Change (sq km)
	As on 24th Aug. 2006	As on 5th Sept. 2006	
Barmer district	244.51	171.91	72.60
Kawas	18.07	17.25	0.82
Malba	5.64	4.66	0.98
Uttarlai	21.03	19.64	1.39

Analysis was continued even after submission of rapid action plan and the status of water spread at later dates is presented in Table 3. The water spread at Kawas on different dates is presented in **Fig. 1**.

Slope, drainage and catchment analysis

Slope, drainage and catchment analysis was done based on interpretation of Digital Elevation Model (DEM) data from Shuttle Radar Topographic Mission(SRTM). Hydrologic interpretation of DEM is based on the fact that it views DEM as a surface that naturally allows flow of water and directs it flow towards channels located at relatively lower elevations in the topography. DEMs are useful for interpretation of flow paths and delineation of catchments and channel network. The SRTM is a joint project between NASA and NGA

Table 3. Status of water spread on 7 dates of passes for Kawas, Malba and Uttarlai

Places	Water spread area (sq. km)						
	24.08.06	05.09.06	15.09.06	29.09.06	04.10.06	12.11.06	01.12.06
Kawas	18.07	17.25	14.83	14.77	14.71	12.87	11.79
Malwa	05.64	04.66	3.95	3.85	3.71	3.33	3.17
Uttarlai	21.03	19.64	19.53	14.32	13.62	12.93	9.30

(National Geospatial-Intelligence Agency) to map the world in three dimensions. The SRTM global data is available at 3 arc second (90 meter). Analysis was carried out separately for Kawas, Malba and Uttarlai villages. The delineated catchments are shown in **Fig. 2**.

Kawas: The Kawas area is located on a natural depression where all the drainages from upper catchment areas meet and converge, resulting in excessive runoff accumulation and flooding in the event of such high and continuous rainfall. Kawas has a catchment area of 2354 sq. km. The width of the channels in this catchment area after this flood event ranges from 158 meter to 1244 meter. Water in this region has flown through three distinct channels passing through following villages. **Fig. 2** shows the delineated catchments.

Matikagol – Khural – Balai – Joranada – Motinada - Pragniyoki Dhani – Chokla - Khanji ka Tala - Chhitar ka Par - Kawas (Distance 186.7 km).
Juneji ki basti - Jalela ki Dhani – Agoriya – Nimbla - Kanji ka Tala - Kawas (Distance 115.4 km).
Vishala, Sonar, Kumbharon ki Dhani, Sar ka Par, Kawas (Distance 109.4 km).

Malba: It has a catchment area of 142.17 sq. km. The length of the two channels contributing for floods at this site is 27.47 kms and 11.00 kms respectively. The elevation between highest and lowest point is 290 meter and 225 metre for the first channel and for the second channel it is 264 meter and 248 meter. The water depth at Malba is up to 15 ft as per 5th September 2006 data.

Uttarlai: It has a catchment area of 250 sq. km. The length of the two major channels contributing for flooding at this site is 35.50 kms and 21.00 kms, respectively. The relief between highest and lowest point is 261 meter and 155 meter, respectively for the first channel and for the second channel it is 235 meter and 155 meter. The water depth at Uttarlai is about 3 ft.

Rapid Action Plan

Based on the analysis carried out using near real time satellite data and field data following action plan was suggested.

- Draining the water through the suggested path up to *Luni* river in case of Kawas. The water will have to be taken out through a channel to be constructed for this purpose and put to natural drain, which runs for 16.57 km un-interrupted of a total distance of 66.37 km up to river *Luni*. Further, there are obstructions due to dunes at four places. The average available gradient between Kawas and *Luni* is 1:745 with elevation being 155 m and 89 m near Kawas and *Luni,* respectively. The obstructions are at the distances of 16.57 km, 20.40 km, 23.69 km and 31.35 km, respectively from Kawas and extend for 2.26 km, 1.44 km, 0.75 km and 0.13 km, totaling to 4.58 km.

- Draining out water through the suggested path and releasing water in Jaldu *Rann* in case of Malwa village. The possible route for draining of water is by cutting dune towards south east of Malwa and joining the flow path leading to Jaldu *rann*. The length of channel is 8.14 km with available gradient as 1: 301 with elevation being 233 m and 206m near Malba and Jaldu *rann,* respectively
- Rehabilitating the people to alternate safer sites of both the villages.
- Looking at the size of the channels formed during this year's flood, water is going to accumulate at these sites even in normal rains (though in lesser quantity) and hence these sites must be declared as unsuitable for retaining as human settlements.

Proposed flood water removal path from Kawas and Uttarlai is shown in **Fig 3**.

Acknowledgements

• Ground Water Department, Jodhpur	• Shri Manvendra Singh, MP Barmer
• Sambhaav, Ahmedabad	• Divisional Commissioner, Jodhpur
• School of Desert Sciences, Jodhpur	• Entire staff, RRSSC/ISRO, Jodhpur

Fig 1: Kawas water spread area on different dates

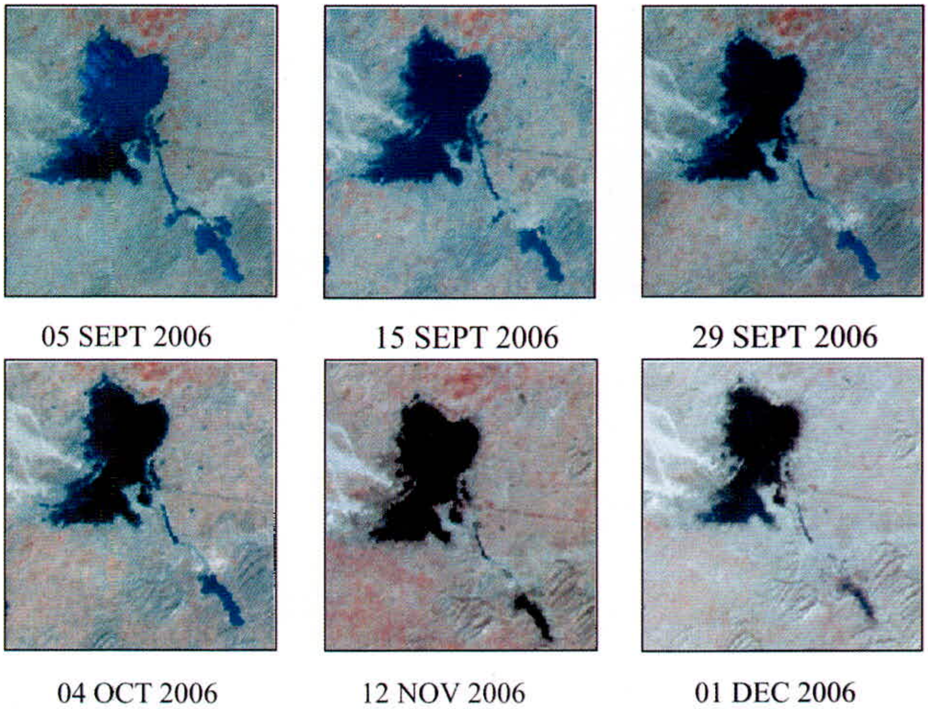

Fig 1: Kawas water spread area on different dates

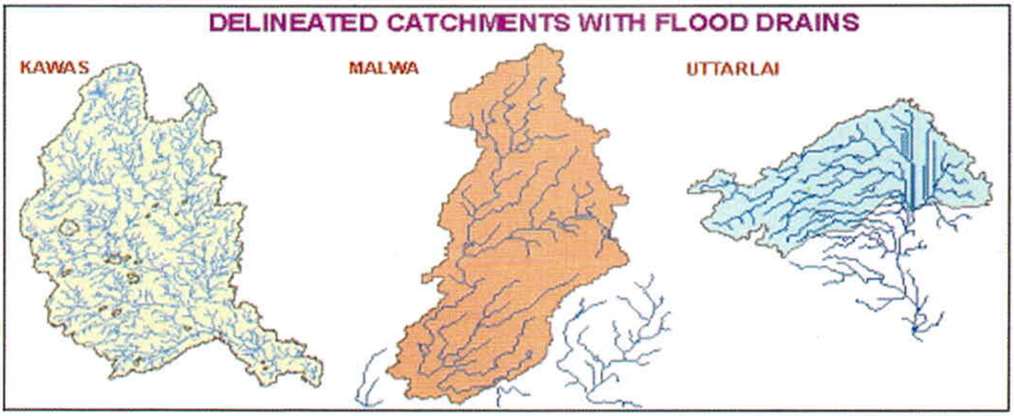

Fig 2: Delineated catchments with flood water

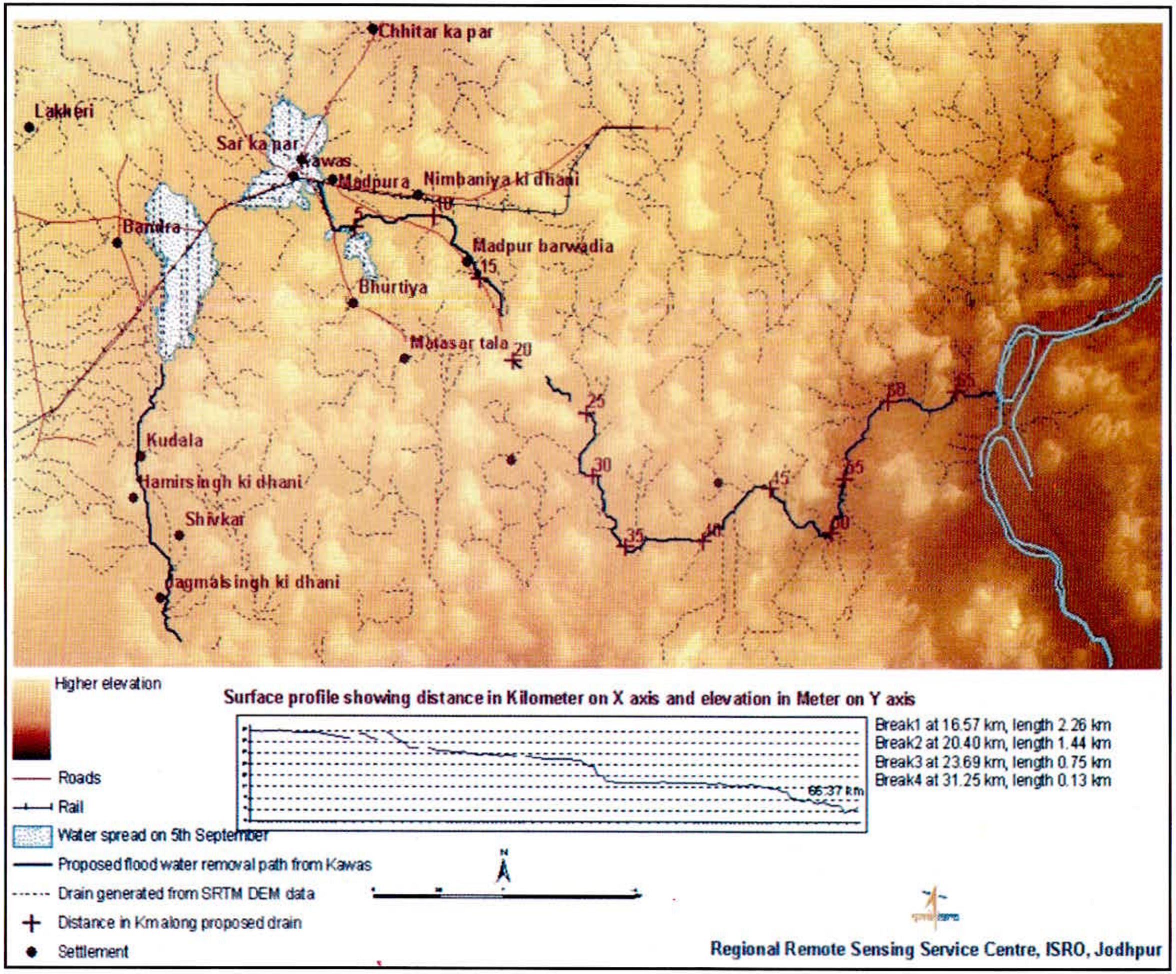

Fig . 3: Proposed flood water removal drain from Kawas to Luni

Floods in Thar

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Floods in desert are rare and uncommon. The arid ecosystem is fragile and vulnerable to harsh environmental fluctuations including flash floods. People and the ecosystem are not prepared to receive sudden torrential down pour. Therefore, floods in arid region are more devastating taking toll of human and animal life and huge loss of infra structure.

The Thar desert, spread in the western part of Rajasthan, receives 100 to 400 mm rainfall annually. Sand dune and sandy plains are dominant formations but at places, in inter dune plains there are massive formations of calcrete, gypsum, bentonite and lignite which restrict deep percolation of water. The *Luni* basin in the eastern fringe of Thar along Aravallis has integrated drainage net work. In rest of the desert disorganized drainage causes pounding of water in low-lying areas.

The Thar receives rains through north eastern monsoon. However, some times, southwesterly winds from Arabian Sea during low pressure also bring rains. Cloud burst or heavy rains associated with monsoonal depression/low pressure system are not unusual. During 1901 to 1997 there were 25 instances of heavy rainfall out of which severe and wide spread floods occurred 7 times. There is a large spatial variability in rainfall resulting in localised floods. In the year 1973, Sam received 1191 mm during 17 days as against annual rainfall of 150 mm. During 1975 many places in Nagaur-Merta area recorded rainfall of 600-900 mm in 4 days. Probability of high rainfall and floods is more in Luni basin. During the period of 88 years Luni basin received 39 floods of various magnitude, the severest being that of 1979 followed by 1973. In the year 1979 rainfall of 500-800 mm during 5 days in upper Luni basin caused havoc along the river courses. In the year 1990 heavy rains were received in Jalor (549 mm), Jodhpur (572 mm) and Barmer (472 mm) in a spell of 4-5 days which caused collapse of precious irrigated holding along the course of streams, bank cutting, scouring and gravel casting (Anonymous, 1990). Most of these floods occurred in Luni which had an integrated drainage net work and flood water found way in the streams. But the flood of 2006 in Kawas and Malba (Barmer) is unique in the sense that the area does not have integrated drainage and there is no outlet for flood water.

Monsoon Scenario of the Year 2006

During 1st June to 22nd July there were sufficient rains in Udaipur, Kota and Jaipur Divisions, moderate in Ajmer and Bharatpur Divisions but Bikaner and Jodhpur divisions received very low rainfall (Table 1). Because of failure of rainfall in Thar desert there was hue and cry with the apprehension that the region is heading towards drought.

Table 1. .Rainfall (mm) received during 1st June to 22nd July in normal years and in the year 2006

Divison	Normal years	Year 2006	
	1 June- 22 July	Pre- Monsoon 1-30 June	Monsoon (1-22 July)
Bikaner	94..58	48.53	30.96
Jodhpur	140.07	50.22	34.38
Ajmer	187.83	54.95	90.47
Bharatpur	208.93	87.52	62.25
Jaipur	178.04	65.61	111.50
Kota	270.93	110.23	103.67
Udaipur	241.66	140.46	178.00

But suddenly on 28th July there were showers in the region, followed by heavy rains on 29th July in the Pali, Jalor and Sirohi areas. Barmer area received moderate rains in Sindhari and Mokalsar area (Table 2) but from 19th August continuously for four days heavy rains started pouring in Barmer and Jaisalmer areas and water got pounded in low lying areas causing flood situations in hundreds of villages. Flood situation in some of the villages is presented in Table 2. The unprecedented flood situation particularly at Kawas, Sar –ka- par and Malba villages took toll of people and livestock, and heavy loss of infrastructure. The Kawas village was under 10-20 feet deep water **(Fig. 1)**. The Uttarlai Air Base got submerged.

Causes of August 2006 flood in Barmer

There were three major causes of flood i) High intensity rainfall during 19-22 August, ii) Depression topography, shallow soils and indurated substrata, and iii) Solum saturated with moisture because of preceding rainfall.

***High intensity rainfall within short span*:** The Barmer district had received 720 mm rainfall in the year 1990 and 600 mm rainfall in 1994 but there was no flood because the rainfall in those years was well distributed. During Aug. 2006 Barmer and adjoining Jaisalmer area received heavy down pore within four days.

***Topographic depression, shallow soils and indurated substrata*:** Continuous rains in Bamer and Shiv tehsils and adjoing Jaisalmer area resulted in excess runoff from Baisala and Kotra hillocks, gravelly and calcreted surfaces spread in the area. The flowing water via. Bhadaka- Rohili- Bandra and Bhadaka – Chokhala – Nagana revived buried channels through which water gushed to Kawas- Uttarlai depressions, even dissecting high sand dunes **(Fig. 2)**. Movement of flowing water towards Luni river was restricted by the exiting high dunes and water pounded in depressions and near Kawas and Uttarlai. The flooded water could not seep below the ground because of shallow soils underlain by indurated calcrete and gypsum substrata **(Fig. 3)** (Joshi 1999 a, b; Sharma *et al.*, 1994). Efforts to

Table 2. Rainfall events and flood scenario

28 July	Jodhpur received first shower of 37 mm
29 July	Pali, Jalor, Sirohi districts received 3-8" rainfall. Near Sumerpur six persons traveling in a car were taken away by flood water
9 August	Moderate rains received at Barmer town (46 mm), Sindhari (75 mm) and Mokalsar (55 mm) disrupted Railways in Bhilari and Samadari Sections.
19 August	Wide spread rains in Marwar, Jalor cut off.
20 August	Barmer district received 60-260 mm rains during last 24 hrs. In Barmer and Balotra towns colonies in low lying area submerged.
21 August	Barmer and Jaisalmer districts each received 135 mm rainfall within 24 hrs. Road, railways and electricity net work disrupted.
22 August	As the result of heavy rains for 72 hrs. hundreds of villages submerged under deep water. During last twenty four hrs Barmer district received 214 mm, Barmer town 171 mm, Baytu 63 mm, Kavas village under 10' water
23 August	Miajalar under 3 feet deep water, On National high way 1500 trucks stranded Between Bachrau and Mangta (Dhorimana). Many people were sick and could not take treatment. Out of 100 persons 66 carried away by flood. Bus coming from Ramdeora was stranded near Bhadka and flood water entered the bus up to roof top. Out of 90 passengers 50 were missing
29 August	Gale ki Basti (Jaisalmer) submerges under deep water spreading in 8 sq. km area. All 118 houses including three pucca houses, school building, community hall and Jhopa submerged.

Source: Rajasthan Patrika, Jodhpur edition

Table 3. Rainfall during 19th to 25th August 2006 at some tehsils of Barmer and Jaisalmer districts

Tehsil/ locations	Rainfall (mm) in August 2006								Total (mm)
	Up to 18th	19th	20th	21st	22nd	23rd	24th	25th	
District Barmer									
Barmer	215.0	40.0	80.0	135.0	171.0	22.0	15.0	0.0	678.0
Baytu	233.0	28.0	64.0	129.0	63.0	8.0	4.0	0.0	629.0
Shiv	102.0	12.0	44.0	130.	125.0	12.0	7.0	5.0	437.0
District Jaisalmer									
Jaisalmer	296.0	68.4	1.0	130.0	1.5	-	0.8	0.0	499.3
Sam	175.0	8.0	75.0	29.0	14.0	2.0	-	0.0	254.0
Fatehgarh	170.0	56.0	12.0	178.0	95.0	6.0	3.0	0.0	518.0

puncture the substrata by heavy drills did not succeed. The 4 to 6 m deep water remained pounded in Kawas for months and even after 300 days water is standing.

Preceding rainfall saturated solum with moisture: Since the soil column of the flood affected area was saturated because of good rain fall received in Barmer and Jaisalmer area up to 18 August (Table 3), there was no infiltration of rain water and high runoff was generated.

Losses due to flood

Disruption of habitation and loss of life: Barmer area received 750 mm rainfall as against normal rainfall of 277 mm which caused sever flood situation affecting 8 lakh people. There was huge loss of livestock and human life. Nearly 52 00 houses collapsed. The affected people were shifted to relief camps.

Damage to mining industry: Kawas area is known for mining of gypsum, lignite and bentonite. Economy of people is mainly based on mining activities. There are about 50 factories, which produce best quality gypsum and supply to factories for manufacture of Plaster of Paris. Out of these, 36 factories got submerged in flood water. Low-grade gypsum is used for agricultural purposes. Fertilizer Corporation of India (FCI) has a good infra structure for gypsum mining. Piles of mined gypsum worth Rs. 70 lakh was carried away by the flood water. In the adjoining villages viz. Bhadka, Botia and Jalipa bentonite mining is being carried out. All these mines were flooded with water and in near future mining of bentonite was hampered. RSMM has huge infra structure for lignite mining which was adversely affected.

Loss to agriculture: Crops worth Rupees 30 crore were lost. Nearly 4 lakh hectare area was affected due to severe and very severe water erosion and sediment deposition. The fertile soils were eroded and at places rills and gulley were formed. Soil conservation and rehabilitation efforts are required to restore productivity of these lands. At other places fine textured sediments to the depth of 30 cm to 90 cm have been deposited. Fine sediments are rich source of nutrients and have good moisture holding capacity and can prove better areas for cropping.

Disruption of road and rail transpor : The road to the flood area were breached and transport could be restored after many months (**Fig 4**). The railway track remained under 3-4 feet deep water and after four months it could be restored.

Wild life: Godawan the endangered bird, depend on *Lasiurus sindicus*. August is time for their reproduction and laying eggs on *Lasiurus sindicus* grass. *Lasiurus sindicus* grasslands were submerged and therefore reproduction of this bird was in danger.

Dewatering of flood water

✓ It is interesting to know about the efforts were made for dewatering the flood water. Water was transported through train to empty in nearby Luni river. Train with 72 tankers was employed which transported 15 lakh litres water per trip and emptied in Luni river. But the efforts could not be continued.

- ✓ Power drills were employed to puncture the substrata so that flood water can enter in deep layers. But there was no down ward movement of water and effort had to be suspended.
- ✓ Efforts were to construct canal to divert water in the Luni river but because of local opposition the efforts were left half way.

The Thar desert had experienced floods in past but the August 2006 flood was unique in many ways viz. high rainfall within a short span of time, typical terrain and lithology of the area, application of advanced satellite technology which quickly made available information on the course of flood water, water spread area, suggestions for short and long term curative and preventive measures and above all the alert media which constantly monitored the relief and rescue operations.

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Fig 1. Kawas village submerged under deep water

Fig. 2 High sand dunes dissected with flood water

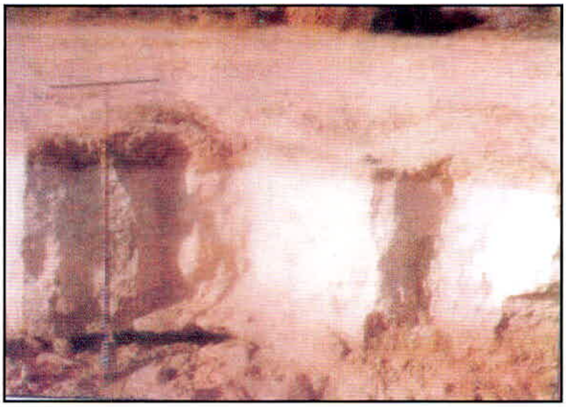

Fig 3. Flood water could not seep below the ground because of gypsum substrata

Fig. 4 Rail and road transport suspended for months

Barmer Flood, 2006: Causes and Consequences

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Introduction

Flood is no stranger to monsoon India. Every year, as the rainy season begins, some part or the other in the country gets flooded, causing loss of life and property, which necessitates huge expenditure on rescue and relief operations. However, much of this is usually restricted to the major river basins in the humid, sub-humid and semi-arid zones. Arid regions, due to paucity of rainfall, experience flood on fewer occasions, especially as a consequence of high-intensity rainfall for a short duration, when the dry channels and the largely sand-covered plains cannot accommodate the amount of runoff generated.

Defining flood is difficult partly because it is a dynamic event, and partly because it is viewed differently by different segments of a society. In general, flood is a high-water stage in which water overflows its natural or artificial banks onto normally dry land, such as a river inundating its riparian plain. In other words, flood occurs when a stream cannot keep the volume of water within its banks. This results in either overflowing of the banks, breaching, or gushing out of water through some topographical low, or re-establishment of the course through some palaeochannels. Flood along rivers can also occur due to many other reasons, like breaching of a dam or a series of soil and water conservation structures like anicuts, etc. While the above definitions of flood are scientifically correct, for common man flood takes place when the river inundates an area or washes away the habitations and belongings. Thus it is considered as a major economic loss and a calamity. Despite such common belief, flood is beneficial for the society in the long run. As the water topples the banks of a river, it carries nutrient-rich silt and other fine particles from the upper catchments to the flooded fields, thus enriching the soils. Moreover, as the stagnated floodwater gradually seeps through the subsoil, it recharges groundwater in the alluvium.

Stream channels are the carriers of runoff and sediment load. In a sand-bed stream, like that in the Thar Desert, there is usually large-scale transportation of bed load and suspended load till the peak discharge stage of a flood event. At that stage, the channel first adapts temporarily to flood discharge with modification of its depth and width. As the width increases and water spills over to floodplain the velocity decreases. Once the discharge drops below the threshold, bed load is dumped in the channel bed and it remains there until the next flood of similar or higher magnitude occurs. Also, there is a cascading effect of channel sedimentation as flood flows of different intensities pass through a stream cross-section during an event or a series of quickly occurring events. Major floods may cause channel widening and scouring during the event, but over the period, the damage is repaired to some extent by deposition. In a sandy desert the eroded areas are gradually covered by wind-blown sand. Part of the aeolian sedimentation is recycled flood deposit.

Flood in the Thar Desert

In the Thar Desert flood occurs during years when rainfall during the monsoon months is exceptionally high and gets concentrated within a few days. Decade-wise flood frequency for the region has shown that broadly 3 out of 10 years are flood years, maximum flood years (moderate to severe) per decade during the last one hundred years being five during 1951-60, 1971-80 and 1991-2000. There is, however, very high spatial variability in the occurrence of flood. In recent memories, the flood in the Luni river basin during September 1967 and July 1979 caused widespread damage to life and property in the tributary catchments to the east of the Luni River, but the areas to the west of it were not affected. The July 1979 flood was largely concentrated in the catchments to the north of the Jawai River, especially in Jodhpur and Pali districts, resulting more than 300 human and about 1 lakh animal death (Dhir *et al.*, 1982). More than 70 small and medium irrigation tanks were also breached. Heavy rains during the first week of July 1990 and then in the first week of August 1990 also caused flood damages in the Luni basin (Kar, 1994). However, unlike during the 1979 flood, this time the high rainfall was concentrated more in the catchment areas of the Jawai and its tributaries in Pali and Sirohi districts, and hence more impact was felt in those districts.

Flood-causing Rainfall in Barmer area

Unlike in the case of drought, western Rajasthan has very sparse written record of flood events. Therefore, to get some idea about the spatial pattern of the previous floods we analyzed the available daily rainfall record on some basic assumptions. Our experience suggests that in most parts of the Thar Desert a rainfall of about 200 mm within a span of 2-4 days leads to enough runoff in the catchment areas of dry sandy streams, which is difficult to contain within the stream beds, thus causing flood.

An analysis of the daily rainfall at Barmer, Chohtan, Shiv and Fatehgarh for the period 1929-1977 revealed that except for 1973 (August) no other years had enough synchronous rainfall at all these stations (Table 1). Subsequently Barmer had flood-causing rainfall in 1990, 1992, 1993 and 2003, while Chohtan had these in 1990, 1992 and 2003. Shiv received flood-causing rainfall in 1993 and 2003, and Fatehgarh in 1993 and 2000.

Table 1: Flood-causing rainfall in Chohtan-Barmer-Shiv-Fatehgarh area (1929-1977)

Year	Chohtan	Barmer	Shiv	Fatehgarh
1929	193.4	-	415.3	-
1931	-	267.2	-	-
1944	381.0	262.9	-	-
1947	-	206.7	-	-
1973	340.0	301.3	277.0	259.0

During the 1979 flood in the Luni basin (15-19 July), Barmer received only 23 mm rainfall, Sindri on Luni River (south of Balotra) received 93.5 mm., while Jodhpur, Bilara and

Pali received 642 mm, 773 mm and 514.5 mm, respectively (Dhir *et al.*, 1982). In other words, rainfall of a major station may not speak for the flood events in a district as a whole. This called for an analysis of the previous records of flood in the region.

August 2006 Flood in Barmer Area

In 2006 the chronically drought-affected districts of Jaisalmer and Barmer received very high monsoon (June-September) rainfall, which caused localized flooding. While Jaisalmer received 473 mm rainfall, Barmer received 750 mm. The rainfall was not uniformly distributed over time and space, but concentrated in few high-intensity spells of 2-4 days and were unevenly distributed. Jaisalmer town and surroundings had a good spell by the end of June, followed by another in the second week of August when 138 mm rainfall was recorded at Jaisalmer town on a single day (7th August), but other stations received 20 mm or less rain. Parts of Barmer district also received some rain during the spell, but these were not enough for stream flow.

The most active phase of monsoon in the two districts was between 17th and 24th August, when both received very high rainfall. In Jaisalmer district Fatehgarh received 361 mm, and Jaisalmer 161 mm. In Barmer district, Barmer town, Ramsar and Gadra Road received more than 400 mm rainfall, while Shiv, Chohtan, Baytu and Guda received 300-400 mm rain. Rainfall intensity was particularly high between 20th and 22nd August (**Fig. 1**). Although the total monsoon rainfall was not the highest ever for the districts (Jaisalmer town received 583 mm in 1944 and 575 in 1917; Barmer town experienced 940 mm in 1944 and 740 mm in 1990), the spatial distribution was such that the catchments of some now-defunct streams got revived, causing enormous flow and consequent flood and inundation in Barmer-Kawas-Shiv-Ramsar area. The maximum casualty and damage to human life was caused at Kawas village where infrastructures related to flourishing gypsum mines were submerged under 4-6 m deep water, while at Malba the flooding of an interdune plain drowned the village. At least nine villages had stagnating water. In order to understand different aspects of the August 2006 flood in Kawas area we carried out a limited study, which is summarised below.

Simulation of Channel Networks and Catchments

Channel patterns shown on the aerial-photo-derived large-scale topographical sheets of the flood-affected northern Barmer and its adjoining parts in Jaislamer district are very much limited due to extreme paucity of rainfall and occurrence of high sand dunes. Contours are also limited by the distribution of high sand dunes. To simulate the contours and the channel patterns in the Fatehgarh-Phalsund-Guda-Barmer-Chohtan-Gadra Road area, therefore, we used the NASA's 3 arc-second (90 m) digital elevation data derived from the Shuttle Radar Topography Mission (SRTM) of Space Shuttle Endeavour that was flown during the year 2000. The minimum length of a viable channel was considered as 500m. The resultant map was then used for generating stream orders (Strahler method) and the 4th and 5th order catchments. The derived maps were ported to different post-flood MODIS-TERRA FCC images (NASA; 250 m resolution) of the area to find relationship between the simulated channel networks and flooding. We show here the SRTM-derived channel and catchment map merged with the MODIS-TERRA image for 5th October 2006 (**Fig. 2**). We also draped the features on NASA's medium resolution (30 m) Landsat TM and ETM+ FCCs for September to find out relationship with the terrain features.

It is apparent that although the channels emanating from the isolated hills and uplands are unable to flow for long distances due to meagre rain and aeolian sand cover, including the sand dunes, potentials for longer flows exist, and that the flooded areas (sinks) lie along those flow paths. Under extreme situations and continuous filling up of the sinks in the dune-covered landscape the east-flowing channels would extend to the Luni River, especially along the regional slope of the land to the south-east, while those flowing westward would cross the international border and towards the Indus plains. These simulations, however, neither consider the strength of the material while executing stream flow, nor the energetics of the flows, but only the filling of individual depressions. Consequently, the simulated flow paths of the streams need to be taken with some caution. We now describe the most important stream catchments in the area that were revived by the August 2006 flood, causing flood at Kawas and enormous damage en-route.

Despite limitations, simulation results reveal that the Kawas depression received water from a vast catchment in the north and northwest, encompassing parts of Barmer and Jaisalmer districts (**Fig. 3**). The stream network partially revived one of the largest right bank tributaries of the Luni, which is now defunct due to aeolian sand invasion. A partly filled up dry channel, called the Rohili River, carries the vestiges of that stream. Earlier, the Lik was known to be the westernmost major tributary of the Luni, having its origin near Bhaniyana-Pokaran and joining the Luni near Tilwara (Kar, 1988).

Our simulation reveals that the longest flow path of the river originates in an upland near Mehreri (SW of Rajgarh in the southern part of Jaisalmer district) where Malani volcanics meet the limestone member of the Lathi Sandstone. From there it flows through the vicinity of Iklali Thali (N of Thanji ki Dhani), Kesar Singh ki Dhani, Amardan ki Dhani, Bhanbiyon ki Dhani (E of Bisu Kalan), Kumharon ki Dhani and Nagurda through a shallow, pedimented surface with occasional compound parabolic dunes, carving a fourth-order drainage basin (**Fig. 4**). South of Nagurda the basin gets defused, but forcing the channel simulation results in continuation of the flow path through Mulji ka Tala, Chokhla and Jogasar Tala to Kawas through a series of compound parabolic dune chains, which create problems of channel maintenance.

A major tributary of this south-flowing stream originates to the west of Shiv in the hilly terrain of Panrohi Dungar (E of Lakha), from where its course could be traced through the vicinity of Jhanphali, Bhenska, Shiv, west of Nimbasar, Rana ki Dhani, to Agoriya where it is met by other major flows from the vicinity of Nimbasar in the NE and from near Balasar, Shiv ki Magri and Kotara in the west. The combined flow passes through Nimbla and Bharka across the National Highway 15. Downstream it tends to meet the Rohili River, but in effect flows almost parallel to it in a SE direction, and caused enormous damage to life and properties downstream of Nimbla. The fourth-order basin carved out by this stream gets lost in the 20-

40 m high parabolic dune chains near Chokhla, where it meets the channel flow from Negurda.

Two more major tributaries meet the above stream from the west. One of these originates in the Baisala hills (Malani volcanics) and flows through Badon ka Par and then the vicinity of Bambi ki Dhani and south of Botiya to flow SE in the name of the Rohili River and drain into the Kawas depression. At Rohli village it is met from the NW by a small but important tributary from the hills to the west of Botiya. The other major stream from the west originates from near Lunu in the hills nearer to Barmer (Malani volcanics), flows almost parallel to the Baisala stream and passes through the vicinity of Chuli Rann before meeting it to the east of Lakhetali near the Kawas depression. During August 2006 flood the Baisala stream from Shiv-Nimbla-Bharka flowed straight into the Rohili near Rohli village, forcing its way through the sand dunes. The combined flow met the stream from Mehreri-Nagurda-Chokhla to the SE of Bandra and drained into the Kawas depression (**Fig. 5**). The longest channel flow path from near Mehreri to Kawas was ~108 kms.

It is interesting to note that another major stream, originating from the Barmer hills and flowing almost parallel to the Lunu stream, meets the Uttarlai depression from where it turns abruptly southward, rather than joining the Kawas depression barely 10 km to the east. Simulation results and remote sensing signatures suggest that this south-flowing stream has the potential to meet the Luni near Gudä, located further to the south-east, despite being obstructed by a number of 15-40 m high compound parabolic dune chains.

All the above major streams draining into the Kawas depression have formed their own 4th order catchments. We may term them as: (1) Mehreri-Nagurda catchment (927.9 km^2), (2) Jhanphali-Shiv-Kotara catchment (525.5 km^2), (3) Baisala-Rohli-Kawas catchment (319.0 km^2), and (4) Lunu-Lakhetalai subcatchment of (3) (191.5 km^2). Catchments 3 and 4 are flanked downstream by a few small interdune catchments (133.9 km^2) from which the Rohili gets water while flowing towards Kawas depression. Surprisingly, the two major catchments from the north and north-west (catchments 1 and 2) do not continue up to Kawas, and end up near the dune-covered tract of Rohli-Chokhla. Beyond this line there is a vast undefined area (401.8 km^2) that could only be bounded by a 5th order catchment (**Fig. 3**). The only defined 4th order catchment extending almost up to Kawas is that of the streams from Baisala-Lunu. Simulation extended some of the stream courses through the undefined zone south of Chokhla-Rohli, into the Kawas depression and beyond it.

Despite the fact that so many streams potentially drain into the Kawas depression, there is very little evidence to suggest that the depression got filled up regularly during the last one hundred years. Also, a rapid reconnaissance of the available heritage satellite data for the region revealed that all the major sinks of Shiv-Gadra Road-Chohtan-Barmer-Uttarlai-Kawas area did not get flooded during any one high rainfall event in the past due to high spatial variability of rainfall in the region.

Flood-Enhancing Terrain Features

Apart from rainfall the typical geomorphological disposition of the region and the geological framework also contributed much to flooding. As discussed earlier, the ephemeral streams, after emanating from the hills and uplands, flow through a wide stretch of pediments formed of calcreted ancient gravels and ferricreted sedimentaries, as well as exposed Cambrian-PreCambrian volcanics (rhyolite and granite) and Tertiary sedimentary beds (sandstone-siltstone-limestone), topped occasionally by a 1-3 m thick aeolian sand cover. Consequently these upper catchments generated huge amount of runoff. Down the slope the flow paths of the streams rest on a moderately deep aeolian plain, interspersed with semi-stabilized parabolic sand dunes (10-30 m high), where the interdunes are floored at 1-5 m average depth by beds of Tertialry sand, clay, bentonite and Fuller's Earth, while the sinks at Kawas and Uttarlai are floored by Quaternary sand-silt-gypsum sequence (Pareek, 1984; Roy and Jakhar, 2002). Both the above situations discouraged downward movement of water and led to water stagnation at favourable locations.

Additionally, a number of anicuts and check dams in the upper catchments in Shiv-Kotara-Nimbla-Baisala area, which were designed for low rainfall of the region, were breached almost simultaneously, leading to a sudden surge of 3-4 m high water column along the dry valleys. This had a catastrophic effect on the sandy channels downstream, as the surging water columns re-established the old channel beds and partially modified them, cutting through the flanks of a number of sand dunes and eroding up to a meter of topsoil. As the combined flow from a number of such channels rushed downstream it swept away not only the humans, animals and their belongings, but also gravels and finer sediments. Consequently, there were formation of new channels, stripping of sediments and loss of precious topsoil in the cultivated fields. The functionality of the Rohili river system was re-established over 2500 km^2 area after at least 3 decades.

There is very little information on the historical flooding of the Kawas depression. Our simulation results suggest that while the westernmost part of the depression, drained by the streams of the Baisala-Lunu catchments, have high potentials of getting flooded, the Shiv-Kotara catchment has much less potential, and the Mehreri-Nagurda catchment has the least. Discussion with villagers indicated that in living memory the 1973 rainfall had caused some flooding in the area, but another flood of greater dimension possibly struck some 70 years ago when the colour of the impounded water was reddish for first few days. This flood could be linked to the 1929 rainfall in the Shiv-Fatehgarh area (Table 1), from where large-scale transportation of the ferruginous materials might have provided the reddish colour to impounded water.

The onrush of water through the Rohili River stopped at Kawas, largely because the shallow natural depression was deepened and widened through decades of gypsum mining for a huge market. A series of high sand dunes downstream of Kawas also prevented any escape route, and the water (>86 mcm) did not recede much even after 4 months due to the thick gypsum layers, followed by rhyolite. The water spread area at Kawas declined marginally from ~17 km^2 in August-end to ~14 km^2 in November. Since the village settlement of Kawas and all the mining-related infrastructures, including the railway facilities, are located within this depression, the flooding caused immense loss to the inhabitants and the state. The nearby depression at Uttarlai, which is also used for gypsum mining, was inundated by another stream from the hills of Barmer-Baisala area. This depression gets flooded more often than the Kawas depression, especially because of the unrestricted flow path of the channels from the catchment in the Barmer hills. At Malba the village settlement is located at the lee of a huge parabolic dune chain, which is always subject to deflation due to its typical disposition. Consequently the local topography has a bowl shape. Some of the dry channels from near Mandaliya and south of Suwala flow into this depression, and have no escape route due to the dune chain downslope. Heavy downpour in Fatehgarh-Shiv area revived the channels and the water flowed into the village settlements. Ignoring the dune chain, the regional slope in the area is to the south, into the major rann at Jaidu. Had the village settlement been located slightly away from the deflation zone, the casualty could have been avoided.

Efforts to drain the water out of the severely affetced Kawas, Uttarlai and Malba depressions did not have the desired success in stipulated time. It also raised questions whether settling people and building infrastructures on natural drainage ways without adequate safeguards could be considered as sound policies. Since breaching of anicuts and other soil and water conservation structures was a major reason for sudden rise in water level in the swollen streams, questions are also raised about the wisdom of constructing anicuts and other soil conservation structures in the upper catchments of such dry areas.

Periodic deposition of the fluvially transported fine sediments in several depressions in the region gradually build up those depressions and contribute to evaporite formation until overwhelmed by moving sand dunes, as was noticed in the excavation of a thick late Quaternary sedimentary sequence along the right bank of the Luni near Khudala (Kar *et al.*, 2001).

Benefits from the flood

Although the flood took immense toll of life and property, and raised legitimate health concerns due to very high incidence of mosquito biting, our assessment suggests some possibilities of turning the calamity into an agricultural opportunity for better livelihood of the people, at least in the lower parts of the catchments. Analysis of impounded water at 11 locations soon after the flood revealed that the average EC was 0.17 dS m^{-1} (range 0.07-0.40 dS m^{-1}), while the average pH was 8.3 (range 7.6-9.2). The sediments that have been washed down from the uplands contain finer particles, including micaceous clays having 8-15 times higher available nitrogen (880-3234 kg ha^{-1}), 3-4 times higher phosphorus (20-55 kg ha^{-1}) and 2-9 times higher potassium (270-1249 kg ha^{-1}) than in the underlying soils. Soil pH is 0.4-0.6 unit lower than in the underlying soil (8.3-8.8). Since a large part of the finer sediments have been washed down to the depressions, there is a possibility of sourcing these fertile sediments from the depressions. Our estimates suggest that the Kawas depression received ~28 thousand tonnes of fine sediments, while Malba depression received ~9 thousand tonnes. When mixed with the sandy soil this sediment can improve water-holding capacity of the soil and increase its fertility status. It is possible that despite the impervious layers in the depressions, the water stored in the depressions will partly seep down to form a perched water zone, and even partly recharge the groundwater in areas floored by fractured rocks, thus becoming a boon for some time.

The flood has provided a rare opportunity to vegetate the otherwise barren sand dunes with locally adapted fruit orchards and fodder trees and shrubs. Many of the flooded narrow interdune plains to the west of Barmer are likely to remain waterlogged at least up to the next summer due to a hard granite basement that is preventing water to seep down, and due to lower evaporation rates during the winter. The sand dunes usually have a poor cover of small shrubs, which are grazed by the high livestock population. Since potable water is now available in the interdunes it could be used to establish a number of locally adapted fruit and fodder shrubs on the lower and middle slopes of the sand dunes through nursery techniques. Once the shrubs get established on the sand dunes these will create a permanent asset for the villagers, especially in terms of fruits, fodder and wood resources.

The major agricultural occupation of the villagers in the area is livestock rearing, supplemented sometimes by cropping during the unpredictable rainy season. Therefore, greening of the dune slopes with little labour and introduction of some management practices at village level may help to ensure fodder supply for the animals. If carried out systematically it will also help to arrest the sand movement and improve the micro-environment at no extra cost. In the vicinity of Kawas and Uttarlai the water could also be used for irrigating the winter crops through sprinklers. Our discussion with stakeholders in the affected areas suggests that these views are most welcome, but require necessary technical and financial support from the government. Enterprising farmers in some areas have taken steps to utilize the impounded water and the conserved moisture for cultivation of cash crops during the rabi season. As a result, the vegetation greenness index for the winter season is much higher than that during the last several years. Also, crop production is expected to be higher than during previous years, despite losses due to aberrant weather in early March 2007.

Conclusions

We conclude that the August 2006 flood, a not-so-common event in the drought-prone Barmer district, partially revived a major right-bank tributary of the Luni River. Out of its four major sub-catchments, the largest from the north through Nagurda experienced channel flow for its full length of 108 kms after seven decades. While high-intensity rainfall for short duration was the major cause for channels being in spate, the almost simultaneous breaching of a number of soil and water conservation structures resulted in a sudden surge of water that proved fatal for many. The terrain conditions, especially the presence of impervious layers at a very shallow depth, and the high sand dunes astride the paths of the channels, were the other contributing factors for higher run-off generation and water stagnation for a long duration.

Despite the high losses caused by the flood, availability of potable water in huge quantity, higher soil moisture and enrichment of the soils in the lower reaches with plant nutrients have provided a rare short-term opportunity to convert the calamity into gain.

Acknowledgement

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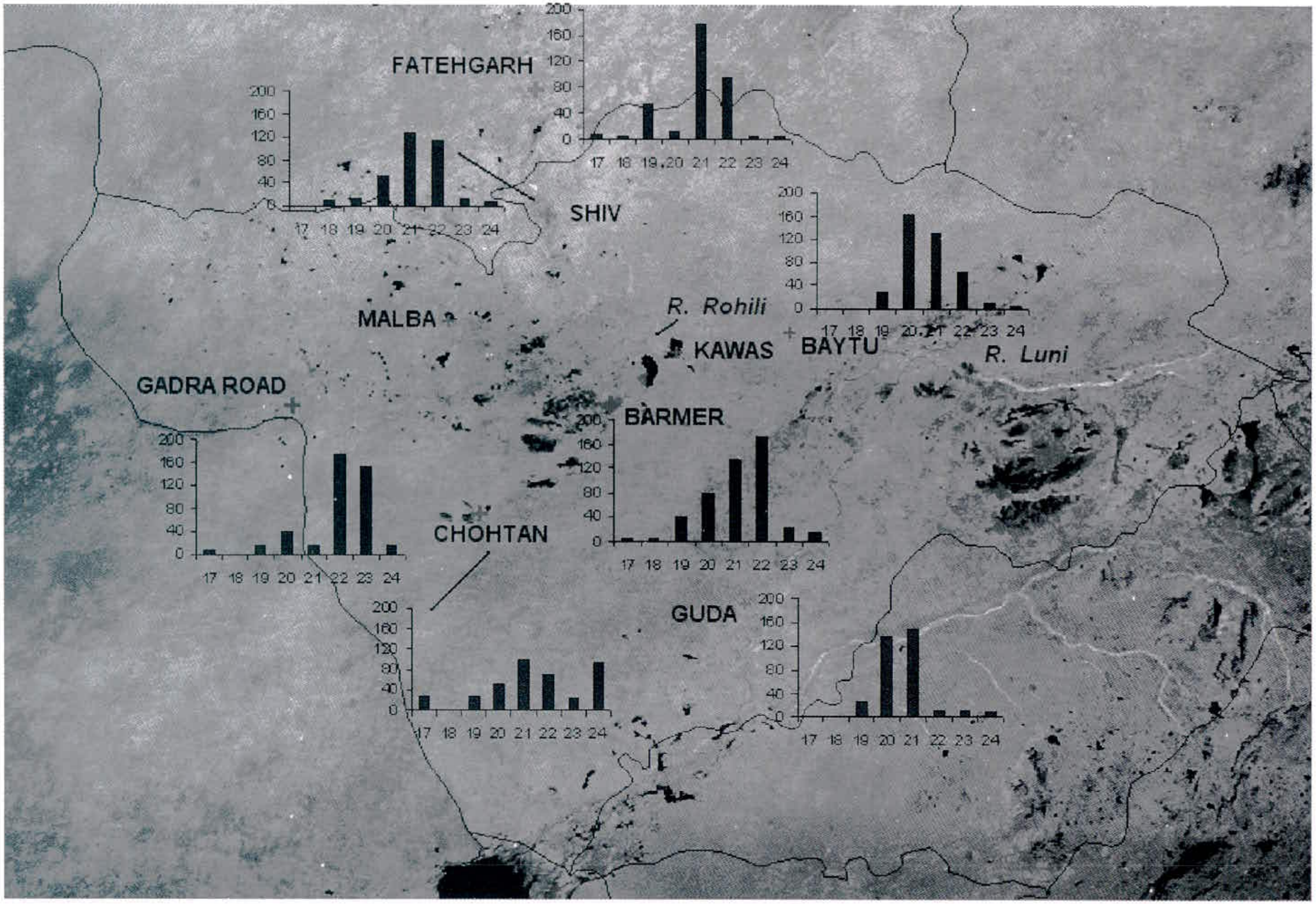

Fig. 1. Rainfall (mm) at different stations of flood-affected areas of Barmer during 17-24 August 2006. Fatehgarh is in Jaisalmer district.

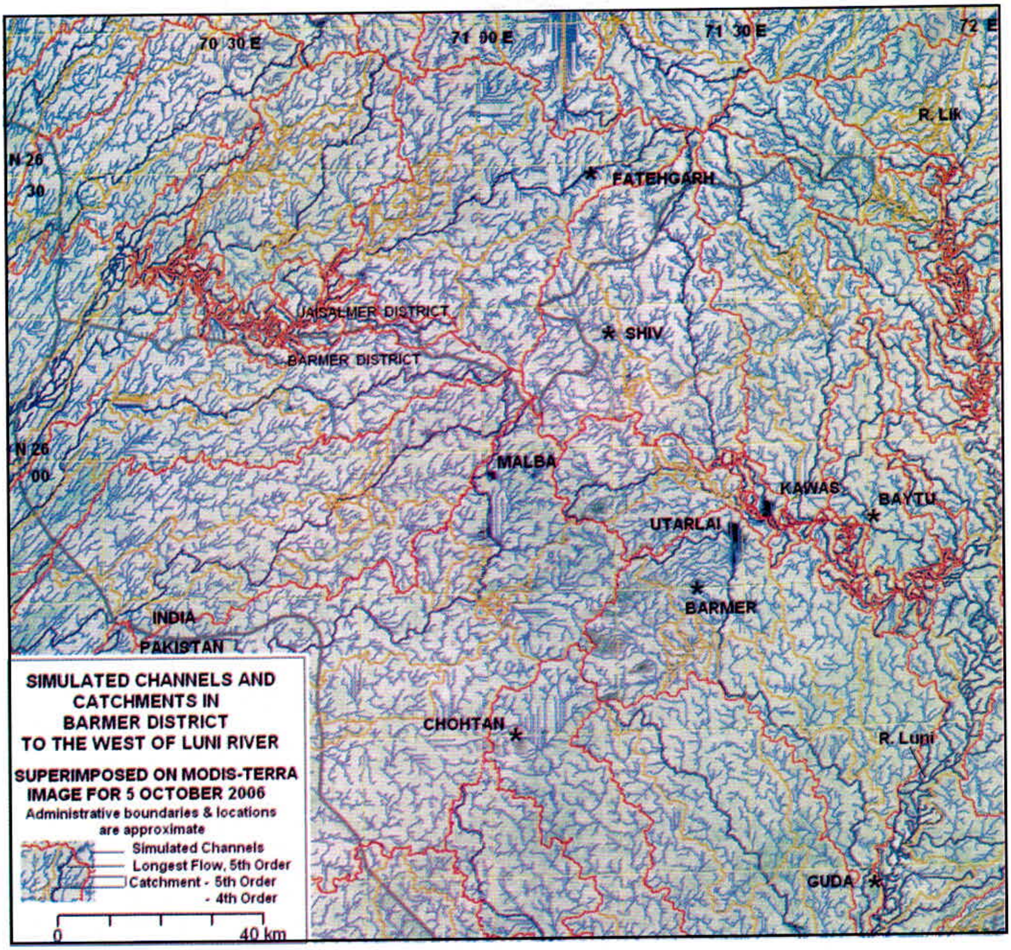

Fig. 2: Simulated channels and catchments in Barmer district to the west of Luni River.

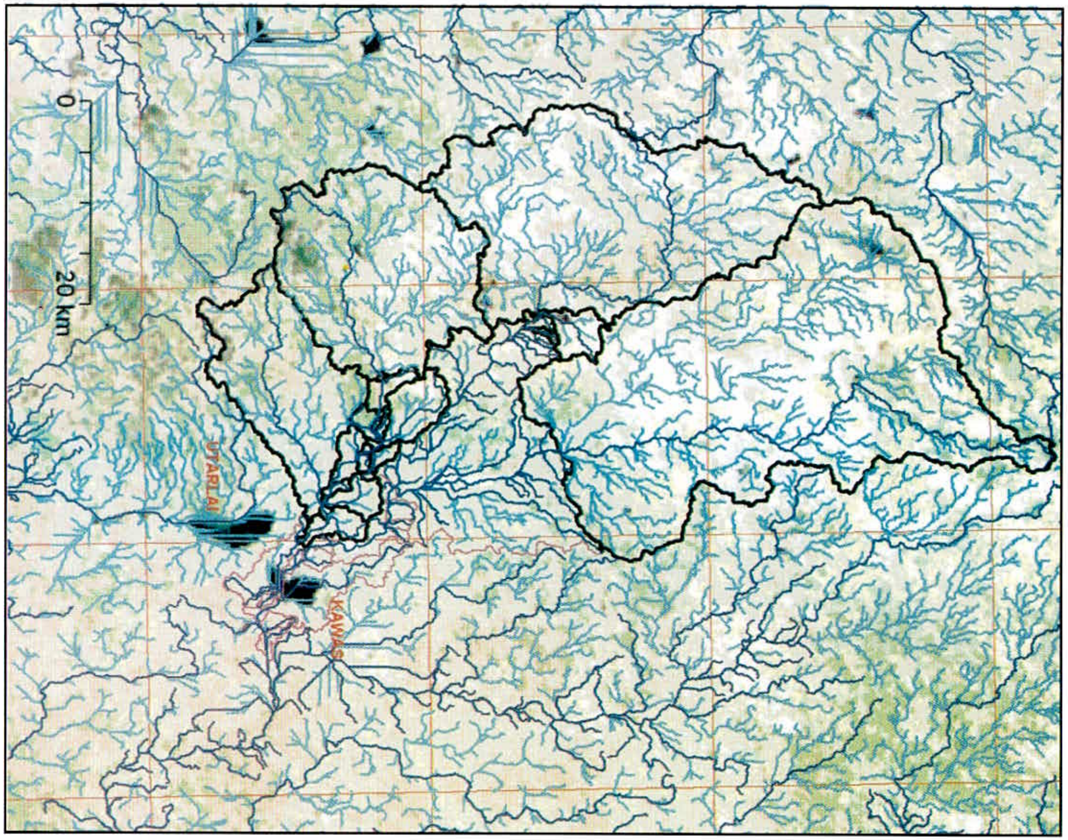

Fig. 3: Simulated fourth order catchments (black), the generated streams (cyan) and the longest flow paths of fourth order channels (blue) in Kawas catchment areas, draped over MODIS-Terra FCC of 5 October 2006. Please note a zone of no defined catchment enclosed between the 4th order and the 5th order (pink) catchments due to closely spaced high sand dunes.

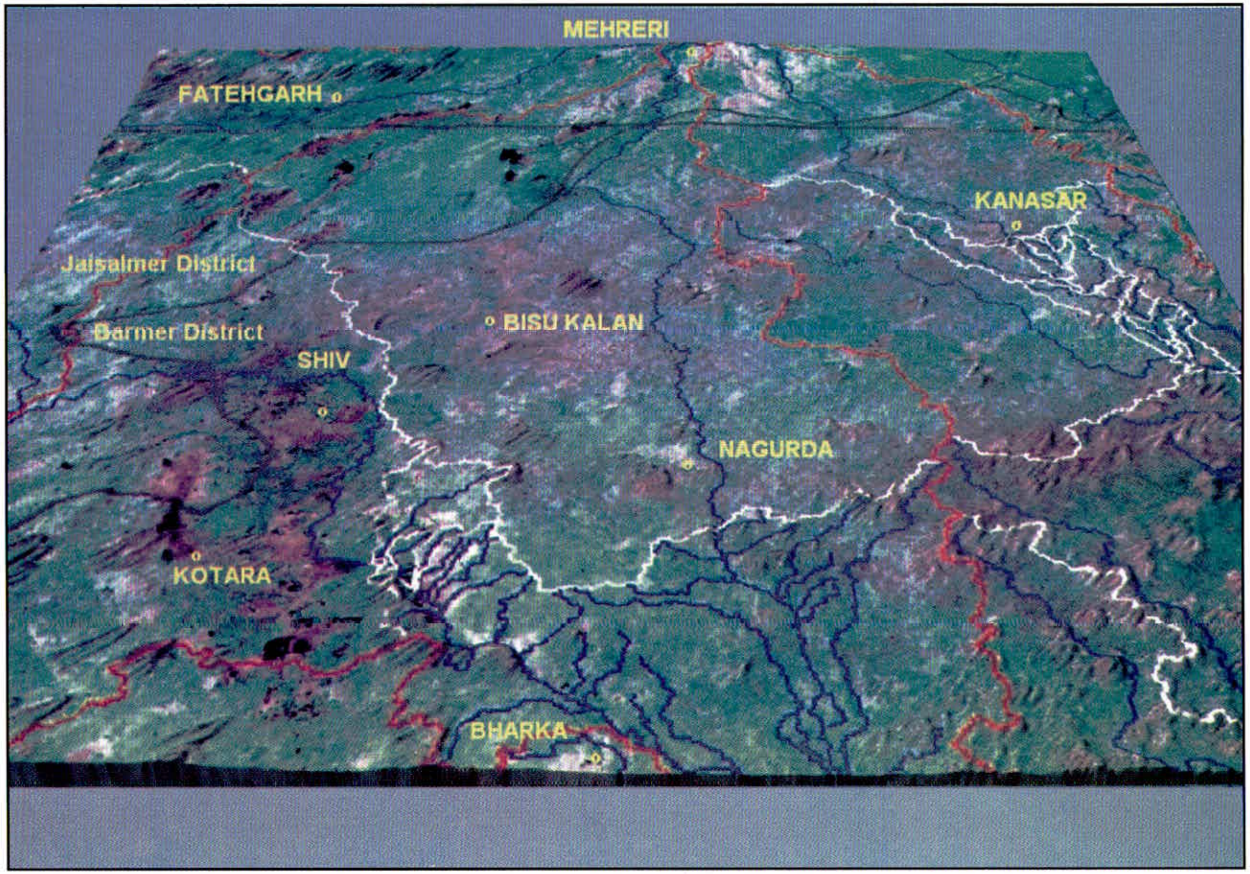

Fig. 4 : 3-D perspective view of the simulated channels and catchments superimposed on Landsat-ETM+ FCC for 21 September 2001, and Shuttle Radar image, showing terrain features in Mehreri-Shiv-Kotara-Nagurda that generated huge run-off for Kawas flood. Fifth order catchments are shown in red and fourth order catchments in white. Major streams are in blue. District

Fig. 5: 3-D perspective view of the MODIS-Terra FCC for 5 October 2006, superimposed on Shuttle Radar image from NASA, showing inundation by the Rohili River system at Kawas and by another river at Utarlai.

Lithology and Terrain Characteristics of August 2006 Flood-Affected Area

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Though rare, floods do occur in the Thar Desert. One such event, which may still be fresh in minds of several of those present today in this gathering, happened in the year 1979. At that time several places in the Upper Luni Basin received rainfall of 600 to 800 mm in a span of less than five days. The resultant run-off concentrated soon into the Luni River and its tributaries to raise the water level of the river to over 5 meters at Luni Junction and 4.6 meters at Samdari (Dhir *et al.*, 1982). The water also spread far beyond its banks to 2-3 km and even more beyond its banks to cause scouring and sand casting of the precious irrigated lands situated along the banks. Irrigation wells and dwellings were devastated and big or small trees were uprooted. The total damage to property and infrastructure was estimated at Rs 100 crore at the then prevailing prices. Besides, 337 persons lost their life and 119 were declared missing

An analysis of the data of the past hundred years at that point of time showed that in the 104 year period, there were 12 years when the Thar Desert as a whole experienced a rainfall that was more than fifty percent of its normal rainfall. Further, in four of these years, the rainfall was in fact double of this value. Of course in the Luni Basin the frequency of such wet spells has been much higher. In a span of 77 years to year 1979, there were four moderate and an equal number of severe floods of fairly wide-spread nature. Of course, floods of localized nature were far more (Table 1). Thus small or big flood events do occur in the Thar once in a while.

Table 1. Past occurrence of likely floods in the basin for the period 1903 – 1979

Extent	Magnitude	
	Moderate	Severe
Localised	1919, 1931, 1937, 1938, 1940, 1947, 1956, 1958, 1961, 1962 (10)	1903, 1905, 1910, 1912, 1916, 1917, 1921, 1924, 1929, 1931, 1945, 1946, 1960, 1967 (14)
Fairly wide spread	1926, 1927, 1972, 1977 (4)	1928, 1941, 1943, 1952 (4)
Wide spread	*1975 (1) (Localised severs)	1907, 1908, 1944, 1973, 1979 (5)

This year (August 2006) one such flood occurred in the central part of Barmer District. A rainfall of 750 mm in a span of four days was received in and around Barmer to cause huge flooding at Kawas, Uttarlai etc. However, the specificity of this flood compared to that of Luni 1979 is two-fold. The flood happened in an area that is devoid of a drainage system worth its name. Secondly, the run-off, which traveled a short distance only, has remained ponded even today, more than 100 days since the wet spell. This makes the Barmer flood scientifically really interesting. The present paper analyses the features that contributed to the generation of a huge rainfall and then made it to pond for months together. Emphasis is on terrain features.

Terrain features of the Barmer area

Much of the run-off that caused flooding originated from the north and north-west of the Barmer Town and these traveled through an ephemeral net work spread over several square kilometers. Though dunes and sandy plains dominate the Thar landscape, this area of Barmer is not typical in this respect of the region. It is made up of ancient surfaces **(Fig. 1)** that came into existence quite a few lac years ago and by a different process as narrated below.

Thickness of aeoilan cover

Several years ago a study was made to map the depth and nature of surficial sediments based on field observations and well logs (Dhir *et al*, 1994). According to that information, the area concerned of Barmer has an aeolian cover of 1-5 meters only **(Fig. 2)**. In fact much of this sand is concentrated in form of a few dune bodies, and a vast majority of this area has a thin aeolian sand cover or is devoid of it altogether. This fact is quite significant as aeolian sands are highly porous and have an exceedingly high infiltration rate (18-25 cm/hour) and constitute an immensely poor terrain for generation and transfer of run-off. Thinness of sand cover seems to be a significant factor in respect of the Barmer flood.

Thickness of other surficial sediments

As stated above much of this area is made up of ancient surfaces in form of alluvial or alluvio-colluvial sediments and rocky or thinly buried pediments. The thickness is less than 5 meters and usually less than 2 meters (**Fig. 3**). Further, these are often consolidated and cemented by secondary carbonate into what is called calcrete. Right at Barmer and in immediate vicinity there is a very strongly developed calcrete right at the surface. From here in northerly direction the calcretes are still there, though not as strongly developed. Futher, it is underlain by Fullers earth, which is an admixture of attapulgite and bentonite clays (Kapurdi Formation). To the south-west of Shiv there is major outcrop of calcrete that this extraordinarily thick (**Fig. 4**). Further on to the east of Gunga, the rocky pediment is strongly calcretised. Beyond this in northerly direction there is a vast area of exposed or thinly buried pediment that is devoid of or has only patchy vegetation cover. To the west of Barmer Town, the colluvium of rhyolites is cemented (**Fig. 5**).

Underlying geological strata

The area concerned is dominated by the Tertiary Formations (**Fig 6 a**). These are represented by the Akli, Mataji-ka-Dungar and Kapurdi formations (Table 2).

The Akli formation is made up of ferruginous sandstone with bentonite clay, gypsum and siliceous earth at lower depths. The Mataji-ka-Dungar is a coarse grained sandstone also with bentonite and other clay beds. The Kapurdi formation, which is youngest of these and also widely exposed, is made up mostly of Fuller's earth., comprising mainlty of attapulgite and bentonite.

Table 2. Geology of Barmer area (After Deshmukh and Misra, 1973; and Roy and Jakhar, 2002)

Age	Formation	Facies/gross lithology
Recent	Dune sands and sediments	Aeolian sands and alluvium
Sub-recent	Uttarlai formation	Thin gypseous limestone and salt sequence
Lower Eocene	Kapurdi formation	Fullers Earth, martine limestone
	Mataji-ka-Dungar formation	Shallow orthoquartzite and sandstone with marine clays
	Akli formation	Bentonite followed by sandstone

Nature of ponded area

The main ponded areas namely, the Kawas and the Uttarlai, are low lying flats. These have at a depth of 50cm to one meter a thick (0.5 to 1.8 meters) lacustral sequence mainly made of gypsum in between there are thin laminations of aeolian sand (**Fig. 6 b**). The strata is quite impervious.

Conclusion

Occurrence of flood and its ponding at Barmer appears surprising. However, we look at the nature of surface cover i.e. the presence of compact, dense surface at or near the surface; the generation of this big volume of run-off and its ponding become understandable features. Of course, the downpour remains the prime mover.

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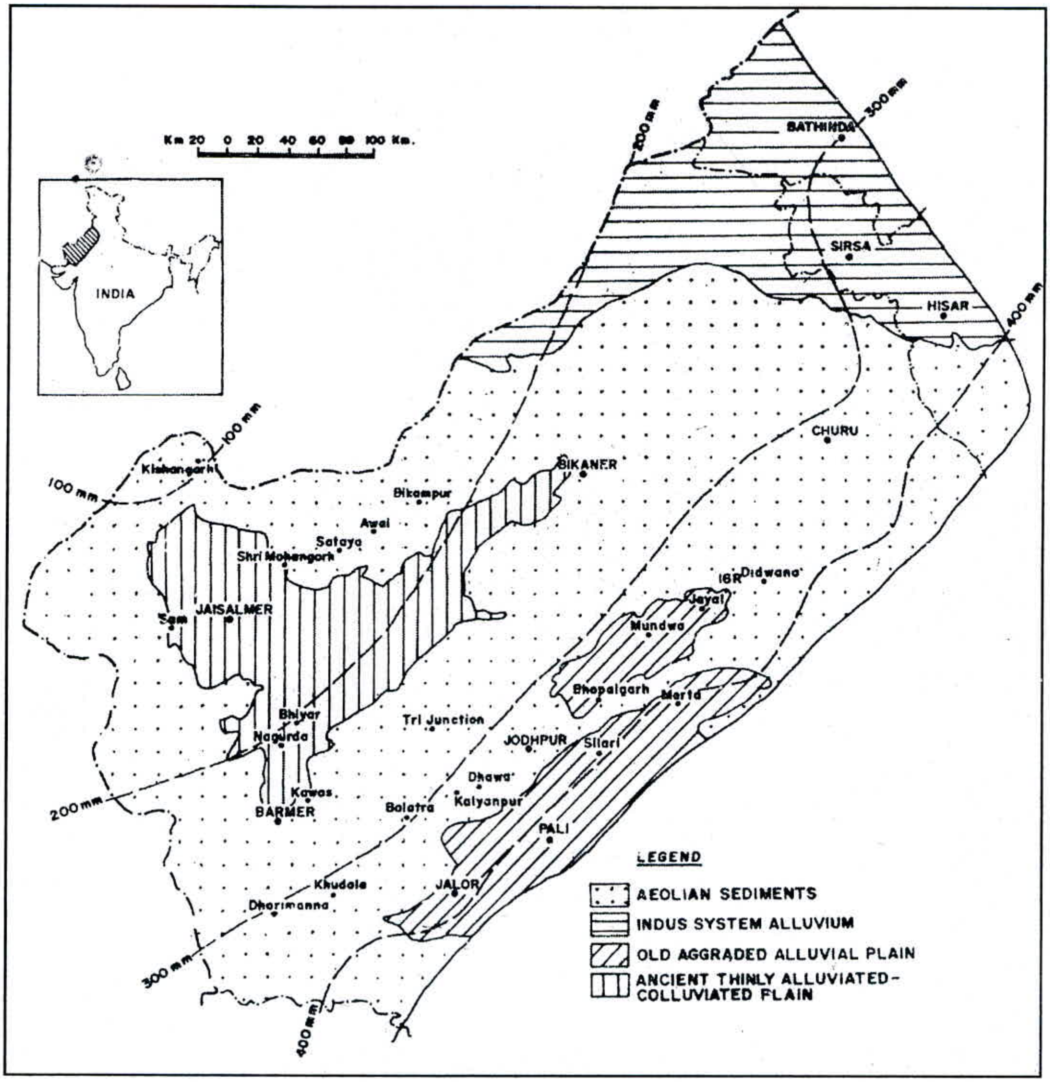

Fig 1 : Ancient surfaces of western Rajasthan

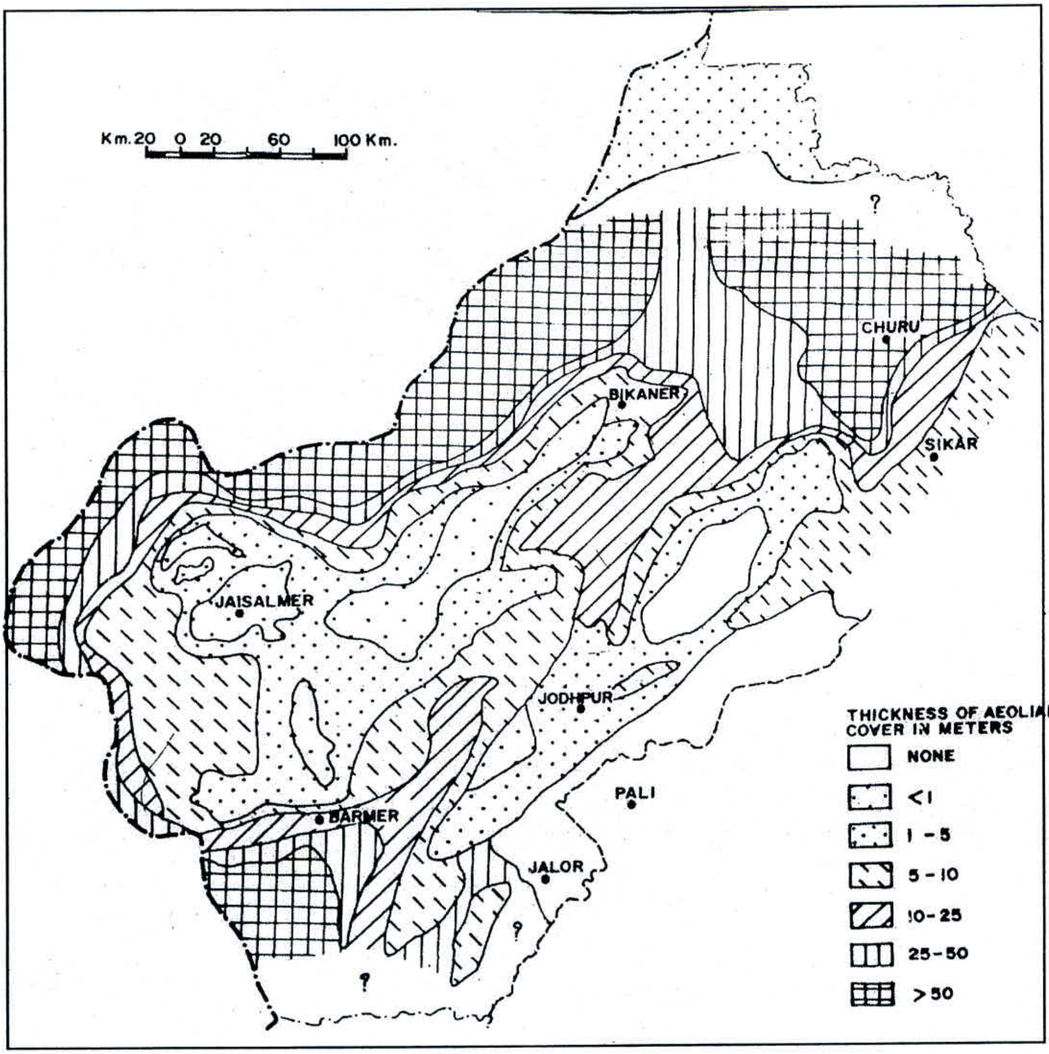

Fig. 2: Thickness of Aeolian cover

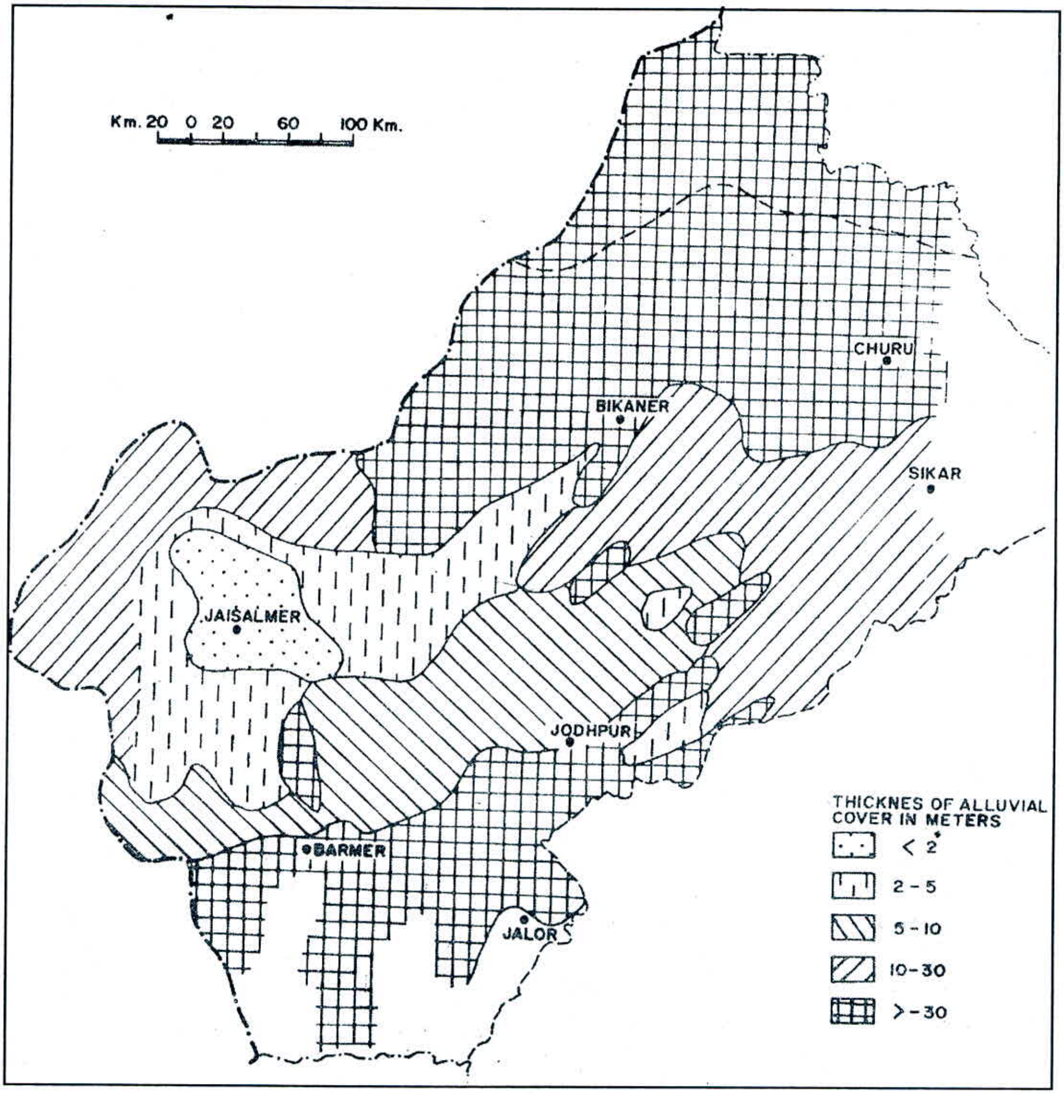

Fig. 3: Thickness of alluvial cover

Fig 4: Calcrete

Fig. 5 : Colluvium of rhyolite

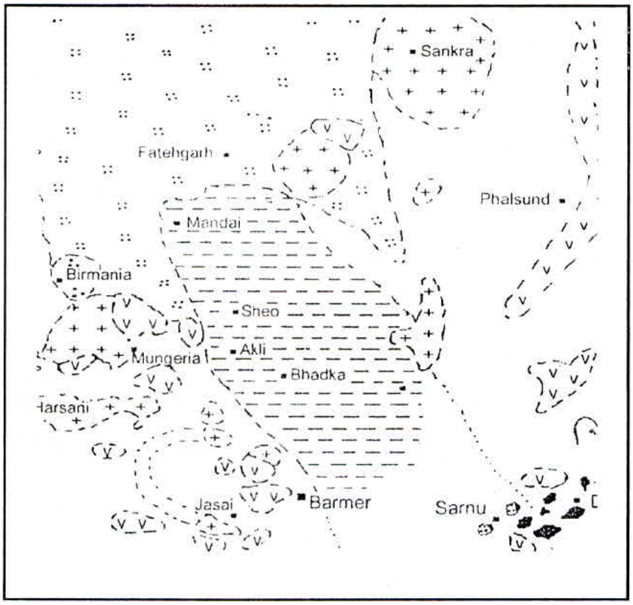

Fig 6 a : Tertiary formations in flood area

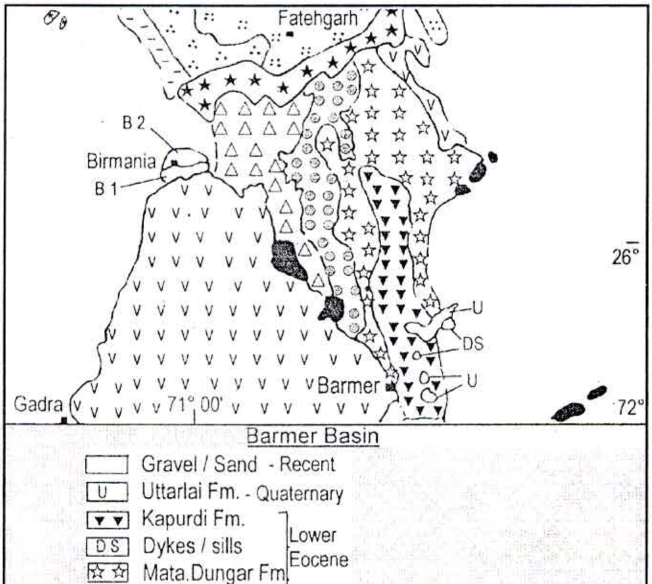

Fig 6 b : Formations at Kawas

Flood Induced Soil Erosion: A Case Study of Barmer District

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Soil erosion is defined as the detachment of soil particles, their transportation from one place to another and deposition elsewhere through water, wind, coastal waves, snow gravity and other forces. Soil erosion involves three steps (i) detachment of soil particles from main body (ii) their transportation by splashing, floating, rolling, dragging and (iii) deposition at another place. The major factors, which encourage detachment of soil particles, are rainfall, vegetation destruction, freezing and thawing, flowing water, wind velocity and lack of soil aggregation. The soil erosion accompanying runoff is usually more serious.

Thar desert, occupying an area of 19.6 million hectares between 22030' to 32005' N latitude and 68005' to 70045' E longitude, in western Rajasthan is covered dominantly by sand dunes and interdunes, active barchans and sub coppice. Alluvial plains are dominantly mapped along the channels. Soils are dominantly non-coherent sandy in nature and are prone to severe erosion. Very low to low water holding capacity of soils, high soil temperature, low organic matter, lower silt and clay content made the soil particles prone to the detachment and transportation from their original place. During the period of heavy storm stream bank erosion, scouring and deepening of channels through runoff water is dominantly observed in the region. The thick gypsum layer, rhyolite, bentonite clay, calcrets and granite below the surface at some depth restrict the downward movement of rainwater thereby aggravating their cutting efficacy. A high frequency of drought and absence of vegetation cover are the other factors, which enhance the efficacy of runoff water to detach and transport the soil particles.

Unprecedented rainfall (348 mm in Barmer, 384 mm in Baytu and 356 mm in Fatehgarh tehsils of Barmer and Jaisalmer districts, respectively) during 19 to 24 August 2006 has created huge runoff. Runoff water flowed from Jalipa-Barmer, Shiv-Kotra and Arang-Bhiyar areas to Kawas and Malba via Rohili-Nimbla and Baisali river systems, respectively. The runoff water was pounded in Kawas and Nand-Malba area because of natural depressions on relatively impervious basement of gypsum-rhyolite and calcrets-granite, respectively. Clogging of natural drainage system because of wind erosion and construction of number of poorly designed anicuts in the drainage lines, were one or the other reason for flood devastation. During the traverse runoff water eroded the channels and damaged the cropland at the upper reaches and deposited the sediment on lower reaches. The manifestation of soil erosion was observed in terms of widening and deepening of channels, scouring of surface material and deposition of sediment on the lower reaches.

Widening and deepening of channels

The runoff flow was so severe that several low sand dunes have been cut through and partly washed out. The channel courses were widen and deepen. The detachment of soil particles was more severe in the upper catchments in Nimbla-Kotara-Shiv area, where the streams have become deeper and wider. Flowing water has explored new courses. The width of the channel in the flood-affected area was reported to have ranged from 158 to 1244 m, which is much higher than the original width (Fig.1). The widening of river course was also reported during the flood in Luni catchments in the year 1979 by 70 to 700 m over and above the original width of the channels.

Soil scouring and sheet erosion

The scouring of soils in the Barmer flood (2006) was observed at many places. The strong current of overflowing water has washed out several anicuts and embankments during its run. The thickness of scoured soil depth varied from 15 to 30 cm. Sometimes 1 to 3 metres scouring of soil profile was noticed (Fig.2). Near Nimbla floodwater in the stream was 3 metres above the bridge, washing out ~ 800 metres of the National Highway. The vanishing of many dunes located in the path of water flow is the example of this kind of erosion. The scouring of soil profiles to the depth of 0.5 to 1 metre was also reported during the flood of 1979 in the Luni catchment.

Deposition of inert sand and fine sediment

During the flash flood of 1979 in the Luni catchment, inert sand was deposited on large stretches of land on either side of the riverbank, while during the present inundation the inert sand was confined to the riverbed. Fine silt and clay size particles were settled in the large area away from the course. Sedimentation of finer particles was thickest (5-10 mm) near Lakheri, whereas 2 –5 mm thickness of sediment was observed elsewhere in the flood affected area (Fig.3)

Soil fertility consideration

Fertility characteristics of the sediment away from the channel particularly at lower reaches of both Rohili-Nimbla and Baisali flow was observed based on the analysis of twenty-six samples. Thirteen samples have been taken from freshly deposited sediment and same numbers of samples were also analyzed from the original soils underlying it. Sediment and soils were sampled from Bhiyar, Kanasar, Naiyoni ki dhani, Bhadka, Lakheri, Kapurdi, Kawas, Nimbla, Malba, Balasar and Nand. Prior to the inundation, soils were loamy sand to sandy in texture. Available nitrogen, phosphorus and potassium content of these soils varied from 88 to 198, 4.5 to 22.5 and 112.5 to 627.0 kg ha-1, respectively. Soil pH ranged from 8.8 to 9.2 and soil organic carbon varied from 0.03 to 0.09 %. After the commencement of the flood a 2 to 5 mm thick layer of sediment, which was silty clay loam to clay loam in texture, was deposited over the soils of the lower catchments. The sediments contained 8 to 15 times higher available nitrogen (880 to 3234 kg ha-1), three to four times phosphorus (19.7 to 54.6 kg ha-1) and two to nine times potassium (270 to 1248.7 kg ha-1) than the underlying soils. A ten to fifteen times higher soil organic carbon content (0.32 to 0.65 %) was estimated, while pH was lowered by 0.4 to 0.6 units (8.3 to 8.8) in the newly deposited sediment as compared to the underlying soils. However, during the flash flood of 1979 in Luni catchment available phosphorus and potassium content was half of the original soils. Micro-nutrient availability was decreased by one third in the fresh sediment as compared to that of underlying soils. The fertility characteristics of the sediment brought during the flood in Luni catchment resembled to that of fresh sediment deposited as a point bar within the channel in the recent Barmer flood.

Reasons of soil fertility enhancement

A phenomenal increase in organic carbon, phosphorus, nitrogen and potassium in the fine sediment (Clay and silt size) collected away from the river course could be attributed to the sheet wash of bentonite rich material of Shiv-Kotara region. The bentonite rich material was reported richer in silt, clay and nutrients than the prevailing loamy sand to sandy soils observed in the flood-affected area. The inert sand deposited in the river course as point bar is generally poor in nutrient reserves. These might have been picked from the aeolian loamy sand to sandy soils eroded during the flood.

Future implications

Silty clay loam to clay loam sediment deposited in the lower reaches on the original soils is the beneficial part of the recent Barmer flood. It has potential to restrict the soil erosion and enhance organic carbon stock and density in soils. Aggregation and water-holding capacity of soils may also be improved considerably. There is the possibility of increasing crop productivity in the region. The sediment can also be used as source of nutrient for the blossoming of plantations and horticultural crops. The pellets of sediment and FYM can also be made and may be used for sand dune fixation and for pasture improvement.

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CAZRI Technical Bulletin 6, 36p.

Fig.1: Widening and deepening of channels

Fig.2. Scouring of soils in flood

Fig.3 Deposition of finer sediment

Flood Disaster in Western Rajasthan: Disadvantages/Benefit

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Introduction

Geological and geomorphological features of western Rajasthan comprise fossils and dunes, interdunal plains, saline depressions, rocky pediments and granitic/ rhyolitic/ sandstones inselbergs (Ramakrishnan and Tiwari, 1998). The geology of the area is represented by numerous litho-strati-graphic sequences ranging in age from the Precambrian to Tertiary periods. Varied lithologies including granites, rhyolytes of Precambrian, sand stone, shales and limestone of Jurrasic and Cretaceous, and sandstone, shales, limestones and evaporites of Tertary, are developed by the dune sands of the Quaternary-Holocene period (Pareek, 1981). These rock masses and consolidated sediments have been developed under extreme diurnal and secular variations in temperature, low precipitation and high potential evapo-transpiration and wind velocity in the Thar Desert. Calcretes (calcium carbonates duri-crust) is the most conspicuous and widely distributed residual deposits and comprised of calcite (5.4-70.5per cent), dolomite (1.2-42.2per cent) and quartz (19.7-54.0per cent) with an increasing percentage of carbonates from powdery calcrets to hardpan type (Raghvan *et al.*, 1986, Krishnan and Tewari, 1997). In general, sand is piled up into huge wind blown dunes, which are of three types viz., longitudinal parabolic (running NNE-SSW, and parallel to the prevailing winds), transverse dunes (aligned across the wind direction, to the east and south of Thar and barchans (with the conclave sides facing the wind in the interior). Surface unevenness is mainly due to sand dunes. The dunes in the south are higher, rising sometimes to 152 m whereas in the north they are lower and rise to 16 m above the ground level. The saline depressions and plains of western Rajsthan are in general regions underlain by Jurrasic shales, tertiary clays and quarternary gypsites and turn into water bodies whenever rain occurs.

Therefore, where even a few drops of rain are considered a boon, the deluge of 2006 has become its bane. In the monsoon season of the year 2006, several villages in the border areas of Barmer were submerged in 3 to 10 metres of water. For countless people in Barmer, the sand dunes became the only homes to stay. The worst affected villages in Barmer were Kawas and Malba. Many people were forced to flee to a sandy hillock with nothing but their lives and the clothes and now battling shortage of food, water and shelter and seem to loss everything except their lives. Losses of livestock have driven many to desperation.

Methodology of Observations Recording

Observations on flow of water and diversion of water channels and formation of riverbeds were monitored physically. Deposition of sands, silt and clay was monitored at different places. Effect on vegetation was monitored in August and September 2006 but detail vegetation study was carried out in February/March 2007. The affected area was stratified (i.e., land after water drying; riverbeds and intact sites) and random plots of 1 ha was laid depending on the latitude and longitude cortisones The survey in these stratified plots was conducted following the method of Khan and Gupta (1960). Flora assemblages were monitored through standardized, quantitative survey using quadrate method. Shrubs and trees were enumerated in the laid 1 ha area. Herbaceous vegetations were monitored in 5 x 5 m^2 quadrate (3 quadrates in the 1 ha plots).

Causes of Flood in Western Rajasthan

Rajasthan is usually struggling with drought and famines. The western Rajasthan experiences 4 drought years in about every 10 years. The temperature varies between minimum of 9° C to the maximum of 45 ° C. Average annual rainfall of Barmer district is 277.5 mm. However, it varied from 207.2 mm in Shiv tehsil to 294.2 mm in Siwana tehsil. . Average annual rainfall of Jaisalmer district is 233 mm. Variations within tehsil's rainfall are relatively greater in Jaisalmer as compared to Barmer district. During monsoon 2006, while west Rajasthan, received 43 per cent above normal rainfall the Barmer received >200per cent above normal and Jaisalmer received 137per cent above normal rainfall (ID&R, 2006). Up to 18th of August 2006, Barmer received about 80 per cent and Jaisalmer about 68 per cent of annual rain (Table 1).

Table 1. Rainfall received from 19th to 25th August 2006 at different tehsils of Barmer and Jaisalmer districts

Tehsil/ locations	Rainfall (mm) in August 2006								Total (mm)
	18th	19th	20th	21st	22nd	23rd	24th	25th	
				District Barmer					
Barmer	215.0	40.0	80.0	135.0	171.0	22.0	15.0	0.0	678.0
Ramsar	206.0	2.0	50.0	55.0	214.0	73.0	21.0	2.0	623.0
Baitu	233.0	28.0	64.0	129.0	63.0	8.0	4.0	0.0	629.0
Shiv	102.0	12.0	44.0	130.	125.0	12.0	7.0	5.0	437.0
Chohtan	344.0	28.0	53.0	98.0	70.0	25.0	43.0	1.0	662.0
Guda Malani	235.0	15.0	86.0	.68.0	60.0	7.0	23.0	1.0	495.0
Shiwana	274.0	27.0	91.0	30.0	12.0	2.0	7.0	7.0	450.0
Pachpadra	160.0	22.0	150.0	80.0	17.0	3.0	5.0	0.0	437.0
Average	221.1								552.0
				District Jaisalmer					
Jaisalmer	296.0	68.4	1.0	130.0	1.5	-	0.8	0.0	499.3
Ramgarh	125.0	4.0	6.0	-	6.0	-	-	0.0	141.0
Sam	175.0	8.0	75.0	29.0	14.0	2.0	-	0.0	254.0
Fatehgarh	170.0	56.0	12.0	178.0	95.0	6.0	3.0	0.0	518.0
Pokaran	96.0	5.0	3.0	12.0	2.0	1.0	1.0	0.0	131.0
Nokh	93.0	6.0	-	5.0	-	-	-	0.0	104.0
Average	159.2								274.6

(Source: Office of the Collector, Barmer and Jaisalmer)

Continuous Rainfall

Continuous rain from 19-24th saturated the soil layers. Rainfall of 21st and 22nd August 2006 particularly in Barmer and Shiv tehsils resulted in excess run-off from the hillocks in Bishala area and Bariada gravely pediment and the Kotra hilly tracts, respectively (Table 1). Elevated dune between Nand and Sura villages made the boundary and the water from Nand, Dudhaberi, Sanua up to Junejon ki Basti villages diverted towards Malba village (Table 2a). Water from Sura-Bishala area flowed toward Bhadka (northward) and mixed with the water flowing from the Shiv area. Likewise water coming from Bariyada area channelised along National Highway-15 (NH-15) and diverted many times in way depending upon the slope and the existing dune resistance (i.e. Gunga village at NH-15) from where the water was divided in two ways. The first flowed from the southern side of Shiv city and passed through Kotra and Nimbali village (along a dune) and crossed the NH-15from south to north near Bhadka. The second was passed over the Shiv-Falsund road (Table 2b).

Table 2a. Flow diversion of flooded water to different areas and accumulation in Maba areas

Village/site	From	To	Latitude	Longitude
Jujenion ki Basti	East	West	26^{0}01’58.3’’	71^{0}08’21.1’’
Nand	Both side		25^{0}58’40.4’’	71^{0}06’49.5’’
Dudhaberi	Both side		25^{0}57’39.1’’	71^{0}02’37.2’’
Malba		Accumulation	25^{0}57’14.8’’	71^{0}01’26.8’’

Table 2b. Flow diversion of flooded water to different areas and accumulation in Kawas areas

Village/site	From	To	Latitude	Longitude
Sura-Bisala diversion				
Sura	North West	East-South		
Baisala	west	east	25^{0}54’30.1’’	71^{0}14’16.2’’
Chooli	West	East	25^{0}51’45.9’’	71^{0}21’14.5’’
Bhadka	Both side		26^{0}00’34.1’’	71^{0}24’52.9’’
Bariyada- Kotra diversion				
Bariada rocky/gravely area	North- East	South-West	26^{0}25’49.9’’	71^{0}12’46.3’’
Khodal village	West	East		
Deveka village	East	West		
Gunga village	West	East		
Shiv-Phalsund Road	North	South	26^{0}13’35.4’’	71^{0}15’43.6’’
Shiv city	Both side		26^{0}11’12.5’’	71^{0}14’39.8’’
Kotara village	North	East South	26^{0}05’31.3’’	71^{0}11’43.6’’
Jadali village	East	West	26^{0}09’57.1’’	71^{0}15’07.6’’
Nimbla village	West- North	East -South	26^{0}03’11.7’’	71^{0}20’08.9’’
NH-15	West	East	26^{0}02’20.4’’	71^{0}20’53.3’’
Bhadka	Both side		26^{0}00’34.0’’	71^{0}24’52.8’’

Drainage Line and Water Harvesting Structures

Continuous rainfall for 36 hrs increased the quantity of surface run-off. However, reduced capacity of the rainwater harvesting structure prepared in different phases by different agencies had also facilitated surface run-off. Some of the observations are:

- ☐ Ineffectiveness of the drainage line filled up by the drifting sands
- ☐ Misuse/ encroachments of drainage lines
- ☐ Decreased capacity of the structures prepared for rainwater harvesting
- ☐ Flaws in/ reliability of the rainwater harvesting structures
- ☐ Weaknesses in our monitoring and forecasting systems

Riverbeds and Flooding of Kawas

Water flowing from the Baisala and Shiv area flooded the villages Bhadka, Rohili, Chokhla, Nagana, Mudo ki Dhani, Bandra, Sar ka par, Dhundha, new Bhurtia and Madpura, etc. Flowing water created two sandy riverbeds even eroded dunes up height of 20-25 m wherever passing through the dune front. The flow of water was facilitated by the channels along the roads i.e., Bhadka –Rohili- Bandra and Bharka-Chokhla-Nagana (Table 3). Both these channels released water in the depression near Kawas. Some of this water over flowed toward Uttarlai, flooding the area covering Uttarlai, Manadion ki Dhani, Kumharon ki colony in Dhundha village and spread up to Kurla Chaklani village.

Table 3. Formation of riverbeds and diversion of water flow from Bharka to Kawas

Village/site	From	To	Latitude	Longitude
River I				
Bhadka	Both side		$26^0$00'34.0''	$71^0$24'52.8''
Rohini	North	South	$25^0$57'30.3''	$71^0$34'37.7''
Mudon ki Dhani	North	South	$25^0$55'21.6''	$71^0$26'26.6''
Jalipa-Dholka	East	West	$25^0$52'46.3''	$71^0$24'37.3''
Jation-Kumharon ki Basti	North-West	South-East	$25^0$34'34.3''	$71^0$25'49.7''
Bandra	North	South	$25^0$52'21.8''	$71^0$30'44.1''
River II				
Chokhla	Both side		$25^0$58'47.5''	$71^0$27'23.8''
Khation ka Tala	Both side		$25^0$57'51.0''	$71^0$29'15.8''
Nagana pumphouse	East	West	$25^0$53'55.7''	$71^0$31'37.6''
Riverbed	North	South	$25^0$56'54.5''	$71^0$30'04.5''
Nagana	North-East	West-South	$25^0$54'35.1''	$71^0$30'24.1''
Allanion ki Dhani (Bandra)	North-West	South East	$25^0$24'49.7''	$71^0$31'49.7''

Water Stagnation and Flooding

Accumulated water in the depression near Kawas as a result of restricted movement towards the Luni basin by the existing dunes and blocked drainage resulted in diversion of water along the Kawas- Bhuratia road and flooded the new Bhurtia village. But restriction by the dune bordering new- and old- Bhurtia villages caused back flow of water towards north east and channelised along the Kawas –Chawa road as well as spreading in the Madpura Barwala village area (including purani Basti along the dunes). Flowing water along the Kawas –Chawa road reached up to Naganion ki Dhani through old Bhuratia and Godaron ki Dhani. near Kawas, the peculiar geology comprising thick layer of gypsum followed by bentonite layer posed major problem in deep percolation of the stagnated water. Drilling the gypsum layer to let the water percolate deep into the ground was not successful, whereas letting the water flow out was also not effective. Considering the evaporation losses of the 10 to 12 feet standing water was a time consuming job. The water flowed towards the Bhuratia, Madpura, Godaron ki Dhani and Naganion ki Dhani villages dried within 10 to 20 days, because of deeper soil layer and the dunes along which the water flowed. However, recent water release by pumping as well as the canal to decant water of Kawas area resulted in water logging in new Bhuratia area affected crops sown area (Observation in March 2007).

Effects of Flood

Soil loss and recovery

Flowing water eroded top soil layer leaving infertile soil at the site. Moving sands from the dunes deposited on the road and agriculture lands may reduce land productivity. However, deposition of silt and clay (mud) in low lying area ranged from 1 mm to 70 mm or even greater in thickness depending upon the depth and time of water stagnation, may enhance soil fertility. In the way deposition of sand was up to a meter depth (i.e., Khation ka Tala, Chokhla).

Effects of flood on economy and agriculture

The flood affected around 17.35 lakh hectares of land, crops of worth Rs 722.21 crores, >2000 families, about 40,000 people as well as business and mining activity. Thousands of homes destroyed and over 50,000 cattle killed. Damage to roads i.e., NH15 and the others, railway line and station requires millions of rupees to tune these up (News). However, presently the farmers of new Bhuratia, Dhundha and at some places in Bandra villages are growing agriculture crops by irrigating with the flooded water. Some of the crops growing in the area are *Plantago ovata* (Isabgol), *Triticum aestivum* (wheat), *Cuminum cymium* (Zeera), *Coriandrum sativum* (coriander), *Brassica* spp. (Sarson), *Cicer arietinum* (Gram), etc.

Effect of flood on vegetation

Western Rajasthan can be divided in to seven ecosystems physiographically. These are: (i) The hills and rock outcrops; (ii) Piedmont slopes; (iii) Alluvial plains; (iv) Saline flats and depressions; (v) Graded river beds (vi) Sand dunes; and (vii) Aquatic areas. These ecosystems are further subdivided depending upon the features of the environment as well as the vegetation (Saxena, 1972). However, the variations in vegetation pattern are not uncommon during catastrophic time. Huge quantity of surface run-off and the pressure generated during water flow damaged the tree, shrubs and the existing vegetation in the way. In some of the cases deposited mud (silt and clay) in the area covered the surface vegetation like grasses and under shrubs i.e., densely populated *L. sindicus* clumps between Rohili and Chokhla villages. Mortality in the clumps up to 20 per cent was observed in this pocket.

A report submitted to the Land Acquisition Officer, Barmer in May 2006 by range forest officer, Baytu on the growth, productivity and cost of *Prosopis cineraria*, *Salvadora oleoides*, *Capparis decidua*, *Ziziphus mauritiana/ nummularia*, *Calotropis procera* etc for Nagana village area indicated that there were very good population of these species in the depressions from where the water flowed. The damages to this vegetation were: *Salvadora oeoides* (1.8 to 2.5 m circumference and 4 to 6 m height, costing Rs 3000 per tree), *Prosopis cineraria* (0.9 to 1.2m circumference and 5 to 7m height costing Rs 2000 per tree) and *Tecomella undulata* (0.6 to 0.8m circumference and 4 to 6m height costing Rs 4000 per tree). Earlier observations on vegetation diversity of these areas also indicated greater population of *S. oleoides* in this area particularly in Nagana village area (Singh, 2004). As a result of water flow, these thickets have been totally lost and the well growing trees have been uprooted. It was observed that trees/ shrubs with surface spreading roots (i.e., *S. oleoides* in particular) were badly uprooted and rolled. *P. cineraria* and *T. undulata*, which have relatively more surface spreading root than the deep penetrating one, were also uprooted. In the recent survey in February and March, greater population of trees and the other vegetation was in the elevated sites, which was not affected by floods. This indicated the effects of flooding on the tree loss (Table 4).

Table 4. Population (per ha) and growth of different tree species in different strata and under the influence of flood in Kawas area

Species	Flooded			Riverbed			Elevated sites		
	Population per ha	Height (m)	GBH (cm)	Population per ha	Height (m)	GBH (cm)	Population per ha	Height (m)	GBH (cm)
P. cineraria	9.0	8.6	109	1.0	6.1	56	10.0	8.4	106
S. oleoides	0.3	-	-	1.2	5.4	127	0.2	3.2	87
T. undulata	0.3	7.8	45	0.2	4.6	32	0.2	6.3	64
Z. mauritiana	1.6	5.6		0.7	3.6	40	11.2	3.4	40
C. decidua	2.6	7.6	39	4.8	3.2	36	2.3	3.6	50
P. juliflora	1.3	4.5	65	-	-	-	-	-	-
C. procera	11.3*	3.6*	30*	5.3	3.7	40	59.8	3.7	60

*Dried

Though, some of the vegetation are coming back in the riverbed as well as the water retreated area in the depressions, but highest population in the elevated area indicated a loss to the vegetation resulting in low population in the riverbed and flooded area (i.e., *A. pseudotomentosa* and *C. burhia*). *D. bipinnata* and *Cyperus rotundus/ arenarius* were regenerating in the heavier soil area whereas *C. biflorus* was regenerating in sandy area wherever the water has been dried up (Table 5).

Effects of water logging on vegetation

At the Kawas area, where water percolation is limited by the presence of gypsum/ bentonite layers, *P. cineraria*, *T. undulata*, *C. decidua* seemed unaffected and remained green even after seven months of water logging. *P. juliflora* became yellow at relatively elevated sites whereas it dried in the deeper water logged areas. *C. procera*, *Z. nummularia*

Table 5. Population of shrubs/ grasses in the flood affected area (5 X 5 m^2 area)

Species	Flooded area	Riverbed	Elevated site
Aerva pseudotomentosa	-	2.8	3.6
Crotalaria burhia	-	10.0	21.0
Desmostachyea bipinnata	31	-	-
Sonela	5.3	14.0	1.0
Convolvulus microphylla	-	1.0	38.3
Fagonia brugieri	-	13.7	52.5
Cenchrus biflorus	25.3	25.8	72.0

and other shrubs submerged into water and dried. However, at new Bhuratia village where soil was sandy and deep *P. cineraria* and *Z. mauritiana* remained green, whereas other vegetations including *T. undulata* dried by March 2007. It was probably due to increasing salinity and prolonged inundation (Froend *et al*., 1987). The adverse impacts of flooding are associated with physiological dysfunctions induced by soil anaerobiosis, which include changes in respiration, photosynthesis, protein synthesis, mineral nutrition, and hormone relations, together with increased exposure to a variety of phytotoxic compounds (Kozlowski, 2002). Under inundation, soil desiccation creates anoxia within the soil profile (Megonigal *et al*., 1993) and chemical oxidation of reduced chemical species generates methane, ammonia, nitrite, ferrous iron and manganous Mn (Stumn, 1992). Such anaerobic conditions affect root growth and inhibit uptake of P, K and Ca resulting in death of the vegetation. However, capacity of *P. cineraria* to withstand prolonged water-logging condition may be due to its capacity to cope up with this problem of anoxia or deep penetration roots where no such condition generated. This needs to be studied.

Summary

For marched western Rajsthan where even a few drops of rain are considered a boon, the rain of August 2006 has become its bane. Continuous rain for 36 hrs increased the quantity of surface run-off and accumulated in such a quantity that engulfed Kawas, Sar ka par and Malba villages and affected many of the village in way. The pressure generated by the flowing water washed away the top soil layers, eroded the dune of up to 20 to 25 m height and created two river beds before discharging water to the depression near Kawas. It caused damage to vegetation, human life and livestock and affected agriculture land, and personal and government properties. However, the people are cultivating agriculture crop in Dhundha, new Bhurtia and some areas of Bandra utilizing this water. Vegetations/ trees are flourishing (*P. cineraria* remained green even after 7 months of inundation) now and many grasses and indigenous species like *P. cineraria*, and *T. undulata* are regenerating. However, some remedial measures like under ground tanks, immediate rehabilitation, capacity building of disaster management and maintenance of drainage line are required as future strategies.

Conclusion and recommendations

Continuous rainfall for 36 hrs increased the quantity of surface run-off, whereas ineffectiveness of the drainage line due to misuse/ encroachments decreased capacity of rainwater harvesting structures, flaws in/ reliability of the rainwater harvesting structures; and weaknesses in our monitoring and forecasting systems enhanced the quantity of run-off. Though not utilized properly, but despite such loss there is change in cropping and the peoples have raised varying agriculture crop under irrigation using the flooded water. However, some of the points still required to be considered at priorities are:

- There is need to rehabilitate the people to a suitable place
- People should be sensitized /community mobilized to cope up with such type of problems in future also.
- Drainage channel should be excavated to minimize the impact of such disaster as future strategy.
- Effective rainwater harvesting structures particularly the under ground should be developed to avoid such huge quantity of surface run-off.

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Flood affected areas in Barmer district

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The affected villages in terms of damages in kharif crops, soil erosion and sedimentation problems were Kawas, Bandra, Kapurdi, Bhadka, Nimbla, Sajitada, Nagurda, Gunga, Shiv, Kananio ki Dhani, Gulanio ki Dhani, Sargila par, Kotda, Nand, Dudha Beri, Malba of tehsils Baytu, Shiv, Ramsar and Barmer. Due to flood four types of under mentioned field situations were observed:

1. Silt deposited (0.25- 2.5 cm thickness)
2. Sand deposited upto 4 ft.
3. Loss of top fertile soil
4. Gully formation

Near Kawas village about 5-7 feet of top soil was washed out along with the water stream and a layer of silt ranging from 0.5-2.5 cm was formed on the soil surface. This layer after drying became very hard and cracks were formed. There was enough moisture present below these layers. Under such conditions crops can only be grown after breaking these cracks. The thin layer can be broken simply by ploughing the land and fields can be prepared for sowing rabi crops. The land was not found suitable for rabi crops where layer of silt was quite thick and dried.

In Gunga village near Shiv, a large amount of coarse sand varying from 2-4 feet thickness was deposited on surface soil. Cultivation of crop where soil deposition was more than 2 feet is not possible, where as in places where soil deposition is less and the soil below is fertile (as in *khadin* area) and sufficient moisture is present in the soil, gram can be sown. In some places of Gunga village farmers were sowing mustard directly without ploughing, conserving the moisture and applying basal fertilizers.

In Gunaniyon ki Dhani near Shiv, the water stream had eroded the top soil (fine clay particles with organic substance) leaving large granules (murram) on soil surface. Soil depth is shallow, but there was enough moisture present in soil. Under such situation, *taramira* crop can be grown successfully. Bunding of fields was suggested to harvest run off water. At several places (like Nimbla & Bhadka), the running water formed gullies of different size and magnitudes. Under such conditions crops can not be raised without bringing them in proper shape and condition.

In some area, the flow of water was gentle and it stagnated for a short period leaving fine layer of fertile soil above the surface of some fields (village Sajitada, Nagurd) which improved soil condition. There was enough moisture to raise rabi crops. In some fields water logging was observed due to presence of murram in sub-surface, under such condition wheat/

barley crops can successfully be raised as rainfed after the field is brought to condition.

Recommendations:

1. Available water at Kawas and Malba villages reservoirs can be utilized for lift irrigation in winter crops.
2. Available soil moisture can be conserved and can be used for growing gram, mustard and *taramira* crops.
3. The available water can be used for planting trees during summer.
4. Fields having silt deposited up to 2.5 cm should be mixed during rainy season to increase water holding capacity of the soil
5. To reduce the soil erosion by water in future, check dams/ anicuts should be constructed and suitable tree/ grass species should be planted to reduce water flow.
6. The economic condition of the farmers was quite poor, therefore, sufficient financial assistances should be provided to them.

Emergence of Water Borne Diseases During Post Flood Period in Rajasthan: Preventive Plan and Management Priorities

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The excessive rains during the year 2006, in Rajasthan has led to flood situation in many of the districts of the state. Flood situation causes number of ecological changes which alter and aggravates the etiology of water borne diseases in the affected belt. The eruption of infectious diseases takes place after accomplishment of incubation period of transported disease pathogens from one to other station. From public health point of view, flood causes human health hazards in the following manner:

- Flood connects biomass/biowaste of two unconnected stations. This water bridge causes exchanges of dead organic matter, sewage, dead animals and industrial wastes of one station with other one which under normal conditions do not exchange their matters, including disease pathogens.
- As a result of transportation of above matter, we expect formation of new pathogen niches in the areas where water logging is formed during post flood situation.
- In addition, we also expect abiotic contamination of water in large water reservoirs which intend to serve the drinking water demands of towns/cities and sub-urbs.

Since eruption of water borne diseases takes place with aggravated regimes, normally logistic support falls short and inaccurate leading to large scale outbreaks of infectious diseases.

During recent flood situation in western Rajasthan, especially in Jaisalmer and Barmer districts, an outbreak of diseases such as viral fevers, Dengue, and Malaria etc. have taken place. While fever cases including malaria cases were experienced within the expected incidence of diseases, viral fever cases including Dengue and Chikungunya have been recorded in the proportion of outbreak situations.

Flood situation is always sudden and an unexpected appearance of water volume in a given area. However, the emergence of human infections occur within the frame of expected appearance only. Infectious diseases during post flood situation normally do not surprise a public health expert and more or less diseases show the classical epidemiological trend of distribution. Since aggravated disease magnitude and its fast spread within a given setting is well expected, there appears to be a distinct possibility that we may formulate an all time plan to meet challenges of infectious disease during post flood situation, get prepared and consolidate resources towards first prevention and then for the management or control of disease outbreaks.

Possible infectious diseases during post flood period and their probable foci

Normally the period of September to November forms the peaking up of activity of pathogenic fauna of various infective diseases in Rajasthan. In the conditions of excessive rains, the areas under the influence of excessive water flow form the target belt for expected emergence of infectious diseases. In addition, the areas receiving in-migration of human natives from adjacent state to Rajasthan, also form the site of importation of new infections or the aggravation of already prevalent infections. The period immediately after flood situation marks the incubation and multiplication time of various disease pathogens. Based on established etiology and epidemiological diseases trends, the infectious diseases likely to appear in Rajasthan, during post flood period, are mentioned below:

- Infective diarrohea
- Infective Hepatitis
- Salmonella causing food poisoning
- Leptospirosis
- Enteric Fever
- Dengue & Chikungunya
- Malaria

Depending upon etiological requirements and time requirement to build up the critical density of disease pathogen, during post flood situation, following sequence of diseases occurrence is normally expected:

Hepatitis> Food poisoning >Leptospirosis >Dengue & Chikungunya and Malaria >Enteric Fever

The probable risk areas for the individual disease outbreaks are likely to be as follows:

Hepatitis : Villages and towns with unsafe water supply, areas with the history of chronic malaria (with Hepatic vulnerability).

Food poisoning : Low economic class with the little choice for the food.

Enteric Fever : Villages and towns with unsafe water supply and safe water supply being damaged during flood.

Leptopirosis: Areas of water logging having received water flow from rodent infested areas.

Dengue and Chikungunya: Area with shallow water loggings, areas of Surat (Gujrat) and Balotra (Barmer, Rajasthan) and adjoining villages and towns where in and out migration of humans.

Malaria: Areas with history of chronic and drug resistant malaria and areas of exchange of human migrations.

Preventive plan against infectious diseases during post flood situation

Each of infectious diseases expected to appear during post flood situation has well defined causes and known epidemiology. A careful enumeration of causative agents, vectors and associated risk factors of each of diseases, need to be the first step for initializing an effective prevention plan. For example, Malaria needs presence of active malaria parasite in the form of *Plasmodium vivax* or *Plasmodium falciparum*, the vector species such as *An. stephensi* and/or An. culcifacies and the suitable temperature and relative humidity to facilitate disease transmission. Wherever, these components and attributes are present in the strength of their density, these can be extrapolated over the areas of their occurrence and disease onset can be predicted. Similar work exercise could be attempted in the case of other disease such as

Dengue and Chikungunya, etc. Application of modern tools such as GIS could help to locate probable risk areas for each of problems such as Cholera, Hepatitis, Enteric fever, Malaria, Dengue and Chikungunya and efforts of the State Governments could be assisted with the prevention plan. What is required is, to prepare before disease onset, consolidate the resources and expertise and launch prevention measures when disease is in sporadic form.

Management plan against infectious diseases during post flood situation

In addition to a prevention plan, a management plan could also be suggested to meet post outbreak requirements. Instead of only characterizing the morbidities, investigating epidemics, epidemiological comprehension of each of above diseases could be made by the apex research organization and advance task groups on Cholera, Hepatitis, Leptospirosis, GIS tract Toxication, Dengue, Chikungunya and Malaria could be formed. There could be well documented sessions of training and demonstration on the epidemiological risk factors of each of disease in the affected areas and skills and promptness to cut transmission chains of diseases could be taught by individual task groups by the on site demonstration of intervention measures.

What to do for outbreak prevention

- Formation of advance task forces for each of diseases
- Identification of risk areas for each individual disease eruption in Gujarat, Rajasthan and Maharasthra, using GIS.
- Identification of key issues to be attempted by the team of scientists viz; preparation of training material for demonstration of disease etiology, developing epidemiological flow charts of disease eruption, aggravation and losses.
- Identification of transmission interruption points for each of above diseases.
- Suggestions to consolidate and prioritize state health resources.

What to do for outbreak management

- Formation of groups of Competent scientists, junior scientists, technicians for each of above diseases.
- Visit of teams to affected areas, meeting with core health administrative group and field health authorities in the affected areas.
- On the spot disease transmission interruption guidance
- Support for the specific diagnosis, laboratory assistance

Modus Operandi

1. Document development for post flood out breaks prevention with participation of competent scientists
2. Document development for post flood outbreak management plan
3. Funds, consumables, equipment and inter-laboratory networking plan and dispatching teams to affected areas.

Influence of August 2006 Flood on Livestock and Remedial Measures

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Kawas and Malba villages of Barmer district were the worst affected by the flash floods of 21st August, 2006 with unprecedented floods after several years of drought, a series of tragic ironies surfaced in the desert villages of Kawas and Malba. The flash floods in Barmer have left the heart of the Thar desert devastated. The lakes were formed in and around the Kawas village in a area of 18.07 km^2 (21.08.2006), 14.71 km^2 (04.10.2006) and now it is 12.87 km^2 according to remote sensing, Jodhpur. The Munnabao-Khokrapar rail link between India and Pakistan has also been suspended (in 3 feet deep water) as flood waters have washed away parts of the track.

Effect on Livestock

Naval boats were used to ferry people to safer places and deliver food packets and drinking water to those still cut off. According to reports, the bodies of thousands of animals were seen floating in the flood waters and the scene in the area was pathetic. Some reports say at least 50,000 animals have died. Officials say more than 40 medical teams distributed medicines in the affected area to avoid threat of an epidemic.

The economy of Malba and Kawas villages was totally dependent on Gypsum exploration and on livestock. Livestock were the source of livelihood to most of the villagers. They earn money by selling milk to the nearby Barmer city. Marginal and small farmers earn most of the money through livestock products.

Mitigating Adverse Effects of Flood on Livestock

General livestock management recommendations

1. Animals be shifted to dry and safer places.
2. Govt. agencies/ NGOs should make available Complete Feed Blocks (CFB) and arrange distribution immediately. Transport of CFB is economical to help in needed areas.
3. Feed and fodder supply should be made available to all evacuated animals.
4. Animals should not be allowed to graze on weeds/ toxic bushes, which normally comes up under such conditions. This may lead to mortality.

Preventive measures against epidemics and diseases

1. Foot and Mouth Disease; Haemorrhagic Septicaemia; Anthrax; Black Quarter; Enterotoximia, surra, Thalaeriosis, Brucellaosis are likely to inflict animals under such conditions. Mass scale vaccination should be undertaken against these diseases.
2. To check parasitic infestation, regular deworming should be done. This practice must be started at the age of 2-weeks followed after 21 days and repeated 3-4 times a year

at regular intervals.

3. Insecticidal spray for control of ticks, flies, mosquitoes, lice, etc. Various insecticides like killex, methrin, malathion, aldrin, etc. may be used.
4. Proper disposal of the dead animals/ carcass is essential.
5. The caracass may be disposed by burning the dead body.

Disposing of dead animals after the flood

The risk to humans from animal carcasses is low, if following precautions are taken:

1. Practice proper hand washing to prevent infection with certain pathogens that may be transmitted from farm animals, including Salmonella and *E. coli.*
2. Secure all food sources and remove any animal carcasses to avoid attracting rats.
3. Wear insect repellent when outdoors. Flooding may lead to more mosquitoes, which can carry disease.
4. Be on the alert for snakes that may be hiding in unusual places after flooding. If you are bitten, try to identify the snake so that if it is poisonous, you can be given the correct antivenin. Do not cut the wound or attempt to suck the venom out. Contact your local emergency department for further care.
5. People working to clean up areas containing swine or poultry carcasses should take the following precautions:

- Wear protective clothing, including waterproof gloves, waterproof boots, and protective eyewear (cover any open wounds).
- Use duct tape to seal tops of gloves and boots to prevent water seepage.
- Wear respiratory protection - an N-95 respirator or better.
- If you smell hydrogen sulphide (a rotten egg smell), get out of the building and call for sanitary help.
- Clean and disinfect all clothing and boots after handling carcass-contaminated materials.
- Wash work clothes separately from street clothes.
- Wash hands thoroughly before placing fingers in mouth (nail biting, etc.).
- Shower and wash hair thoroughly after handling carcass-contaminated materials.
- Call your local animal care and control agency for further instructions and to request pickup.

How to Use Flood Water

There are many options suggested by the scientists and officials of the state about removing of water from the Kawas and Malba villages. The efforts for removing water with the help of trains and pumping the water to safer palaces by powerful diesel pumps and recharging of ground water did not succeed. Keeping these in mind the long term planning of flood water to use it for irrigation purposes in a scientific manner is required so that it does not leave any harmful effect on desert soil and its ecology. On sand dunes and community lands pastures and silvipasture can be established to supply the fodder to animals and to engage the population in this activity. This will have beneficial effects not only on village economy but also on desert ecology. There are different methods of pasture establishment by the flood water. In the receded area of flood, fodder crops like bajra, sorghum, guar, cowpea, mothbean should be raised to capture the available soil fertility for higher fodder production. But to some extent cultivated crops may be raised for production of grains.

Effect of Flood of August 2006 in Arid Rajasthan on Animal Wealth in Kawas and Malba areas.

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The sudden flood of August, 2006 on dated 22nd submerged the Kawas and Malba area of Barmer district affecting about 50,000 numbers of livestock head causing mortality of not less than 35,000. The water depth of the submerged area was so high that the rescue operation was difficult even for the affected human population and livestock was left unattended. The total numbers of livestock carcasses recovered by various agencies like the State Animal Husbandry Department, Panchayat Samitis and other voluntary agencies have been recorded to about 10,000 but many animal bodies have remained submerged polluting the stagnated water and may remain cause for emergence and spread of infectious and contagious diseases.

The immediate effect on sheep, goats and cattle was Pneumonia due to continuous down pour of rain and exposure of animals to the wet conditions. As the water was not cleared from the area for many days, presently the various ecto and endo parasitic infestations are being observed in the surviving livestock. One of the main parasitic infestations observed in sheep, goat and cattle is of Liver Fluke as there was sadden emergence of intermediary host- snails which is uncommon phenomenon in situations of arid areas. In addition, the viral infection of contagious ecthyma was also observed in the goat population.

The immediate measures taken by the Government and non Govt. agencies were *en mass* deworming of the livestock with broad spectrum anthelmintic and treatment of sick animals mainly suffering from Pneumonia and GI disorders. In order to protect the surviving livestock from most common infectious diseases the vaccination was done for Haemorrhagic Septicaemia, Black Quarter, Sheep Pox and Enterotoxaemia. The population was also advised to be protected from FMD and foot-rot.

The submerged area had no fodder/crop yield and the pastures lands in the area were also water logged. Therefore the feeds were not available for the livestock in the area but in the adjoining area due to sufficient or more than sufficient rainfall the fodder is available in the form of crop residues or pasture grasses. For the surviving livestock in affected areas the fodder can be supplied from the non water logged area. The priority therefore remains to protect the animals from the infections and contagious diseases and ensuring sufficient feed and fodder supply.

Influence of August 2006 Flood on Wild Life and Rodents

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The North- western hot arid region of India covers an area of about 2,85,680 Sq kms and 60% of it lies in Rajasthan. Climate in the region is characterized by large variation in temperature (lowest: - 4.4°c, highest: 50°c) and erratic and low rainfall (80-500 mm annual). Undulating topography, vast plains of sand interspersed with hilly outcrops, rocks and large gravel plains are characteristics of this region.

Floods in Barmer

Droughts are very common in arid regions but floods though rare are not new in the Thar Desert. Barmer district has recorded three heavy rainfall events in the years 1908 (673 mm), 1944 (940 mm) and 1990 (740 mm).

In the year 2006, heavy rains were received at Barmer (426 mm), Ramsar (392 mm) and Baitu (364 mm) in three days only from19 to 22 August 2006. Water accumulated in the villages viz. Kawas, Malba and Sar ka Par. Several houses were damaged and huge loss of property, human life and livestock was reported. Even after 3 months large area is under water. Many residents have been rendered homeless. The Government and NGOs worked hard for relief and rehabilitation of suffering population on war footing. Efforts were made to pump out water and use for irrigation of rabi crops.

Major Wildlife Species in Indian Desert

Indian desert depicts a rich faunal diversity. There are several wild fauna occurring in open forests, scrublands, grasslands, hummocks and sand dunes in sandy, rocky, or gravelly habitats of desert biome. These may be ground dwellers and fossorial, like reptiles and arboreal bird species. The Mammalian fauna includes, small mammals like rodents, shrews, bats, mongoose, hares etc; medium sized mammals like, monkeys, *Sus*, fox, hyana, jackals etc and large sized, Blue bulls, blackbuck, chinkara etc.

Reptiles

(i) *Lizards*:The region is adorned by several colourful and fascinating reptilian species. These are mainly ground dwellers and fossorial in habit represented by snakes and lizards. Among lizard out of 7 small lizard species occurring in Thar desert only 3 species have been reported from Barmer district i.e., *Cryptodactylus* (1 sp) and *Hemidactylus* (2 sp). Similarly, three species of Agmas viz., Calotes (1sp) and *Agma aeglis* and *A. minor* are also encountered in the district. Large sized lizards, like, *Uromastix hardwickei* (sanda), *Chameolon zealinicus, Ophiomorous tridactylus* (Indian sand skink) and two monitor lizards, *Varanus gressius* and *V.bengalensis* have also been reported from Barmer.

(ii) *Snakes*: Twenty-five species of snakes have been reported from Thar Desert. Commonly occurring snake species in western Rajasthan are: Brahiminy blind snake, *Ramphotyphlops braminą* Sand boa, *Eryx johni* ,Glossy bellied racer, *Argyrogena ventromaculatus* Indian krait, *Bungarus caeruleus* cobra, *Naja naja*, saw scaled viper, *Echis carinatus.*

BIRDS

More than 100 species of birds are reported from western Rajasthan. Common birds in Desert tracts of Barmer and Jaisalmer are: Crows, Myanas, Pigeons, Blue Jays, Hoppoes, Bulbuls, Robins, Sand grouse, Peafowls & Great Indian Bustard. Bird Diversity in IGNP areas of Jaisalmer district has tremendously increased in last two decades due to large-scale tree plantations along the canal banks and shelterbelts. These have provided an excellent habitat (perching and nesting sites) for birds.

MAMMALS

The Indian desert is inhabited by over 60 species belonging to nine orders of class Mammalia. Of this about 79% species are small mammals of order Chiroptera (18 sp), Rodentia (18 sp) and Carnivora (14 sp). The order Chiroptera mainly includes may species of bats, whereas, order Rodentia comprises of porcupines, squirrels, rats, mice, gerbils etc. and wild animals like dogs, hyana, wolf, cats, foxes, mongoose etc are important carnivores in the desert. Other wild mammals include 4 species of order Insectivora (Suncus and *Hemichinus*); two species of Primates (monkeys and langoors); one species each of order Pholidota (*Mannis crassicaudata*); Pressodactyla (*Equas hemionus khur*); and Lagomorpha (*Lepus nigricola*). Four species of order Artiodactyla comprising *Sus*, chinkara, black buck and bluebull also occur in wild in the arid region.

(i) *Large Mammals*: These include Blue Bulls (Neel Gai), *Boselaphus tragacamulus,* Indian Gazelle(Chinkara), *Gazella bennettii* and Indian Antelope (Black buck), *Antelope cervicapra.* These species are well distributed in western Rajasthan but their population is on decline in last few years due to habitat shrinkage and other human activities.

The habitat preference, herd size, movement routes and other behavioural manifestation including feeding and breeding are detailed in Table 1.

(ii) Rodents: These are quadra pedal small mammals characterized by presence of one pair of chisels shaped ever growing incisor teeth (Incisor growth rate: 0.4mm/day) in each jaw and the canine teeth are absent leaving a wide gap called diastema. Rodents possess well-developed sense of smell, hear and touch and are colour blind but can distinguish shades. These animals are mostly omnivorous and may be cannibalistic also. A few species like *Funambullus pennanti* and *Vandeleuria oleracea,* are arboreal in habit whereas majority of field rodents are fossorial, eg. porcupines, gerbils, field rats, mice etc. *Rattus rattus* and *Mus musculus* are two commensal species and live in houses stores and godowns. Except squirrels, bush rats and desert gerbils that are diurnal all other species are nocturnal. In desert biome *Gerbillus nanus* and *Rattus cutchicus* exclusively occur in sandy and rocky habitats respectively, whereas *Mus musculus* and *M. booduga* are reported from ruderal habitats only. Other rodent species share more than one habitats in arid zone.

Table 1: Habit preference and behaviour of blue bull, chinkara and black buck

Characters	Black buck	Chinkara	Blue bull
Habitat preference	Plains, flat and scrublands, saline flats with 1-2 water holes, gravelly wastelands and hard pans	Salt ranges, sand dunes, sandy plains gravelly patches	Hills, gravelly plains, piedmont plains with bushes, loamy soils near crop fields
Herd behaviour & herd size	Gregarious (80-120)	Less Gregarious (herd size not fixed)	Does are gregarious (3-35)
Movement routes	Fixed tracks (jumps up to 1-2 feet)	Not fixed	Not fixed (jumps over 2 m)
Feeding habits	Mainly grazer	Mainly browser	Browser & grazer
Feeding rhythm	Morning till noon & evening seldom in nights	Early hours and late afternoon, Whole day in winters	Early morning and late evening
Breeding	Year round, mainly Feb-March	Non seasonal	Nov. - Feb.
Gestation period (Days)	170-180	150-170	240-250
Litter size	1	1-2	1-2 (twins common)

Breeding season for majority of desert rodents is during monsoon season (July-September coinciding with availability of green food and moderate temperature and high relative humidity. Breeding activity is minimum in extreme winters and summers. Mothers can sustain better health and nutrition during pregnancy and lactation in monsoon months and when young ones wean, enough green and nutritious food is available in nature. Gestation period for different rodent species is as: *Tatera indica:* 27-30 days, *Meriones hurrianae:* 28-30 days, *Rattus meltada:* 20 days, *Funambulus pennanti:* 42 days, *Hystrics indica :* 109 days. The litter size of the rodents varies from 1-9 with an annual productivity of 17-52 youngs/female/ year.

Effects of Floods on Wild Life

Scientific data are not available on adverse effects of recent floods on wildlife and rodents in Barmer area. Smaller animals like fossorial reptiles and rodents inhabiting the submerged areas may have suffered due to destruction of their habitat. Many of them might have migrated to safer/ higher places in their home range. Our experience in cyclone-affected areas in coastal Andhra Pradesh indicates that rodents do suffer due to extensive destruction of their burrows and their population is greatly reduced. However after receding of cyclonic floods the rodents change over to r pattern of breeding for some periods due to availability of enough space without any intra specific competitions and their population attains peak in shorter periods and cause devastations in rabi crops. Thus the population loss in rodents due to floods in Barmer may get compensated through faster breeding in absence of inter/intra competitions and increased rodent population may pose problem in winter crops. Arboreal rodents like squirrels and tree mouse too may have experienced stress in foraging and feeding during floods. Some lizards are reported to have got displaced due to floods and species like *Varanus bengalensis* and *Uromastix hardwickei* having medicinal value were hard hit by floods. *Chamaeleon zeylinicus,* endemic to Thar and Indian sand skink, *Ophiomorous tridactylus* also known as sand fish of desert suffered due to habitat loss in recent floods. No adverse effect on arboreal bird fauna was reported from flood affected areas of Barmer and Jaisalmer, however ground dwellers either shifted to higher places or may have suffered. As reported by media and government agencies, many livestock animals like cattle, sheep and goats died in this flood, however no such information is available for higher wild animals. Probably they suffered less during flooding of their natural habitats as they may have migrated to higher and safer places with similar habitats.

Detailed investigations are needed on: effect of floods on wild life and rodents, changes in faunal bio-diversity and natural food web (prey- predator aspects), breeding profiles of native fauna and risk of rodent borne diseases in the area.

Remote Sensing and GIS Based Study to Suggest Short and Long Term Flood Management / Prevention Plan

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State Remote Sensing Application Centre, Jodhpur

Introduction

Barmer district witnessed an unprecedented heavy rainfall continuously during last week of August, 2006 bringing about 400 mm rainfall in a very limited spell of four days. As a result of this all the water bodies were filled up and many of them breached resulting in heavy flow in ephemeral drains and large runoff so that low lying area especially Kawas, Malba, Sar ka par and Uttarlai were inundated (**Fig. 1**) resulting in loss of human life and livestock and heavy damage to settlements, infra structure and property.

State Remote Sensing Application Centre (SRSAC) realizing seriousness of situation interpreted satellite data to demarcate inundated areas, analyzed rainfall data and various thematic maps for terrain characteristics including landforms, soils, land use, correlated with secondary data and undertaken ground truth verification to suggest short term and long term action plan to utilize flood water and preventive measures for future.

Methodology

Base map of study area was prepared using SOI topo-sheets. The Indian Remote Sensing Satellite LISS III and AWiFS data of September 04, 15th September 06, 29th November 2006 and 8th December 2006 were interpreted for land use/land cover, landforms, soils, road/settlement, surface spread of water at various locations and number of water bodies. Secondary data on rainfall, temperature and population were collected from concerned sources. Hydro-geological studies were carried out. Ground verification under taken to determine ground levels using high precision GPS with sub meter 2-axis accuracy. Based on correlation of inputs observations short term and long term plan for flood water management are suggested.

Rainfall analysis

Tehsil wise average rainfall and total rainfall received during monsoon 2006 presented in Table 1 revealed that Barmer tehsil received highest rainfall (704 mm) followed by Chohtan (686 mm), Baytu (675 mm), Ramsar (670 mm) and Guda Malani (526 mm). These tehsils received more than 150 per cent of rainfall. Very high rainfall received during 4 days spell (19-22 August 06, Table 2) caused flood inundating the low lying area.

Terrain characteristics

The available thematic maps on geomorphology slope and soils were analyzed. The Kawas and adjoining area mainly consisted of pediments with hard substrata underneath.

Table 1. Rainfall received during monsoon season of 2006 in Barmer district

Tehsil	Mean annual Rainfall (mm)	Rainfall received during monsoon 2006 (mm)	% Increase
Barmer	245	704	187
Baytu	257	675	163
Shiv	207	452	118
Ramsar	214	670	213
Gudamalani	245	526	115
Siwana	295	496	69
Chohtan	282	686	143
Pachpadra	285	478	68
Average	254	586	131

Table 2. Rainfall during 19 to 22 August, 2006 (in mm)

Tehsil	Upto 18-8-06	19-8-06	20-8-06	21-8-06	22-8-06	Total 9 to 22 August 06
Barmer	215	40	80	135	171	426
Baytu	233	28	164	129	63	384
Ramsar	206	2	50	55	214	321
Shiv	102	12	44	130	125	311
Chohtan	344	28	53	98	70	249

The Kawas , Malba and Uttarlai area are located in depressions. Soils of study area are shallow, underlain by Petrogypsids, Petrocalcids and hard rocks. These soils qualify for land capability class III and IV marginally sited for cultivation and class VI and VII unsuitable for arable cropping. (**Fig 2**, Table 3).

Table 3. Soil and land capability classification in Kawas and adjoining area

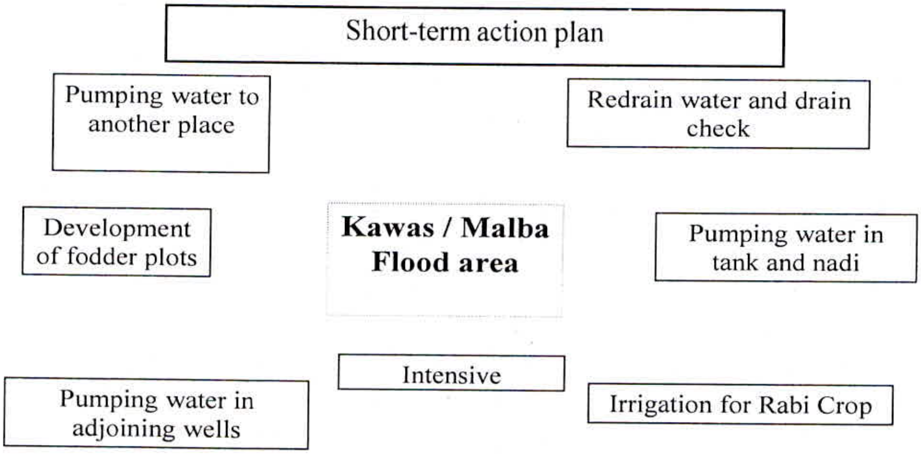
Map Symbol	Classification	Land Capability Class
1	Typic Torripsamments	IV
3	Coarse loamy, Typic Haplocalcids	IV
4	Coarse loamy Typic Haplocambids	III
6	Coarse loamy Typic Haplocalcids	IV
9	Loamy Typic Petrocalcids	IV
11	Loamy skeletal Lithic Haplocambids	VI
14	Typic Torripsamments	VI
15	Loamy skeletal Lithic Torriorthents	VI
16	Loamy skeletal Lithic Torriorthents	VII
19	Typic Torripsamments	VII
20	Coarse loamy Typic Pertrogypsids	VII

Water spread in flood affected area

The IRS P 6 LISS III Images of 15 September and 26 November 06 revealed that surface spread of water ar Kawas was 1366.64 ha and 1262.93 ha respectively. Interpretation of these data revealed that water bodies in Kawas and Malba catchments were 51 on 15 September 06 which were reduced to 36 on 26th November 06. Because of inundation of vast area there were casualty of human life and animals. The road and train transport was cutoff. Habitants were shifted to relief camps and rescue operations were carried out at full swing.

Short term Action Plan

Soon after flood there were efforts to either seep down the flood water by puncturing the impermeable strata or drain out in the near by Luni river. Efforts made in both the direction did not succeed. Water is boon for desert, instead of draining it waste, even if some portion of it is used, the natural resourcescan be developed on sustainable basis. Therefore following short term action plan are suggested to take advantage of this water.



Implementation of National Horticulture Mission Project : There is provision of about Rs. 10.00 lakhs under National Horticulture Mission for construction of water storage tanks for group of farmers, who may use the water through drip irrigation for horticulture plantation.

Irrigation for Rabi Crop- Taramira : Most of area around Kawas and Malba have shallow soils but suitable for Rabi cultivation. Looking to late season current feasibility is only for mustard – Taramira which requires one time irrigation.

Development of fodder Plants: Land use maps prepared using satellite image indicated waste lands including open scrub lands. These areas can be developed into fodder plots for preserving fodder.

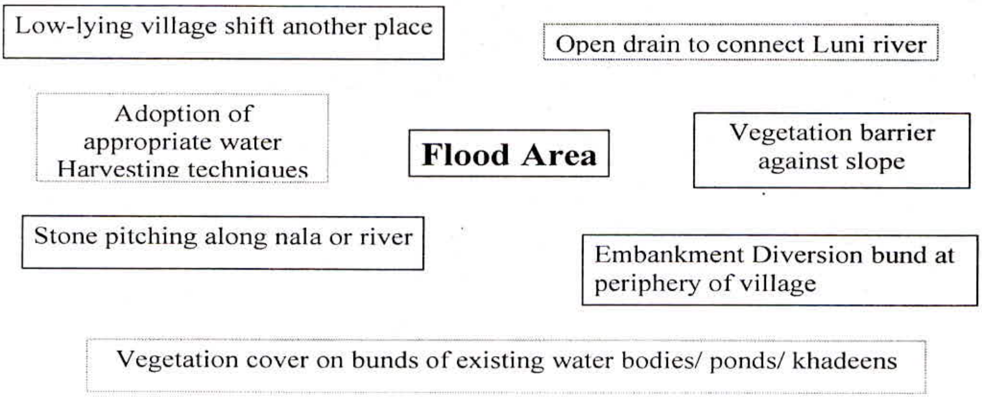
Sand dune stabilization : Forest Department has an important project under the name "Drought Combat", sand dunes stabilization can be intensified under the activity.

Ground water recharge: Ground Water reports suggest that southern part of Kawas has saline ground water > 8000 μs EC, recharging / draining water down ward will not benefit ground water. Instead northern part of Barmer, South East of Kawas around Bharka, Bhimra, Nagurda are good potential areas, acquifer is tertiary sand stone depth upto 60 meter. If wells of these regions are charged with the flood water, it will help a lot. Average potential evapo-transpiration of Barmer is about 1800 mm, average depth of water around Kawas is 1 to 1.5 metre, though urgent measures are being taken to pump out water, naturally most of water will also be evaporated by May-June, 07. It is need of hour that maximum utilization of water should be made as per above plan.

Path for drainage of flood water: If the circumstances compel for immediate drain out, then a canal from Kawas to Sindri and Luni River. Levels at number of locations as shown in map passing through – Kawas, Chawa, Sindri were measured suggesting suitable path for draining out water to Luni (**Fig 3**). Likewise Malba water may be drained southwards towards Rann.

Long Term Action Plan

The long term action plan based on satellite data interpretations are suggested to avoid any calamity in future. These are elaborated below and presented below.



Construction of anicuts: Construction of anicuts at nine locations near Bisala village in catchment of Kawas at following sites (Table 4)and locations shown in **Fig 4** which will help in controlling runoff. The area is catchment of streams contributing to Rohili river.

Table 4: Location and catchment area of proposed anicut sites in Kawas area

Anicut No.	Location	Catchment Area (ha)
A-1	2 Km West of village Baisala	140.85
A-2	3.2 Km West of village Baisala	137.47
A-3	3.6 Km West of village Vishala Baisala	80.83
A-4	2.8 Km East of village Jawant Singh ki Dhani	241.35
A-5	2.5 Km East of village Kanora	134.86
A-6	1.3 Km West of village Tirsingra	341.50
A-7	0.9 Km North West of village Tirsingra	52.18
A-8	1.5 Km North of village Tirsingra	79.57
A-9	1.5 Km South of village Vishala (Baisala)	154.46

Construction of Diversion bunds and water storage ponds/ nadies: Open scrub lands having gentle slope have been delineated. Diversion bunds near Harvecha, Bhenska, Baisala, etc. village have been proposed to divert water from adjoining stream to these waste lands (Table 5). Diversion bunds across stream course, preferably near open scrub/ waste lands may be constructed so that spreading water does not cause damage to cultivated areas (**Fig 5**). It is also proposed that water storage ponds/ nadies should be erected in these gently sloping lands to harvest water during future heavy rains and reduce velocity of water.

Table 5. Proposed sites of diversion bunds and ponds in Kawas catchment

S. No.	Symbol	Location
1.	DB-1	Approx. 1.0 Km. North of village Harwecha
2.	DB-2	Approx. 2.0 Km. S-W of village Harwecha
3.	DB-3	Approx. 2.0 Km. West of village Bhenska
4.	DB-4	Approx. 1.5 Km. West of village Harwecha
5.	DB-5	Approx. 3.0 Km. S-W of village Kotaral
6.	DB-6	Approx. 3.0 Km. S-W of village Jalela Ki Dhani
7.	DB-7	Approx. 2.0 Km. S-W of village Bayro Tiba
8.	DB-8	Approx. 0.5 Km. North of village Jornada
9.	DB-9	Approx. 2.0 Km. S-W of village Nagorda
10.	DB-10	Approx. 2.0 Km. South of village Nagorda
11.	DB-11	Approx 0.5 Km. West of village Nimbla
12.	DB-12	Approx 0.5 Km. South of village Nimbla
13.	DB-13	Approx 1.5 Km. East of village Khyale ka dhora
14.	DB-14	Approx 2.5 Km. West of village Bhambhi Ki Dhani
15.	DB-15	Approx 1.5 Km. North of village Harwa

Peripheral bunds along periphery of villages: Erection of peripheral bunds along periphery of villages to divert water in Kawas catchment are proposed at following sites

S. No.	Symbol	Location
1.	PB-1	West of Village Nimbla
2.	PB-2	East of Village Chokhla
3.	PB-3	East of Village Fakiron ki dhani
4.	PB-4	East of Fakiron ki dhani
5.	PB-5	West of Kumaharon ki dhani
6.	PB-6	North of Meghwalon ki dhani
7.	PB-7	South of Memdon ki dhani
8.	PB-8	East of Legon ki dhani
9.	PB-9	South of Khatiyan ki dhani

- Vegetation barriers against slope, along stream course and vegetation cover of appropriate grasses/ shrubs along bunds of existing water harvesting structures are also proposed.
- Rehabilitation of mining and gypsiferous areas by adopting silvi pasture techniques.
- Shifting inundated habitations to elevated locations which are presently lying as open scrub lands.

Thus by using the satellite images the short term action plan has been suggested so that the pounded water can be used to vegetate the sand dunes, waste lands can be developed into fodder plots and growing low water requiring crops like mustard and taramira. Long term measures include construction of anicuts, diversion channels and diversion channel to drain water in the Luni river.

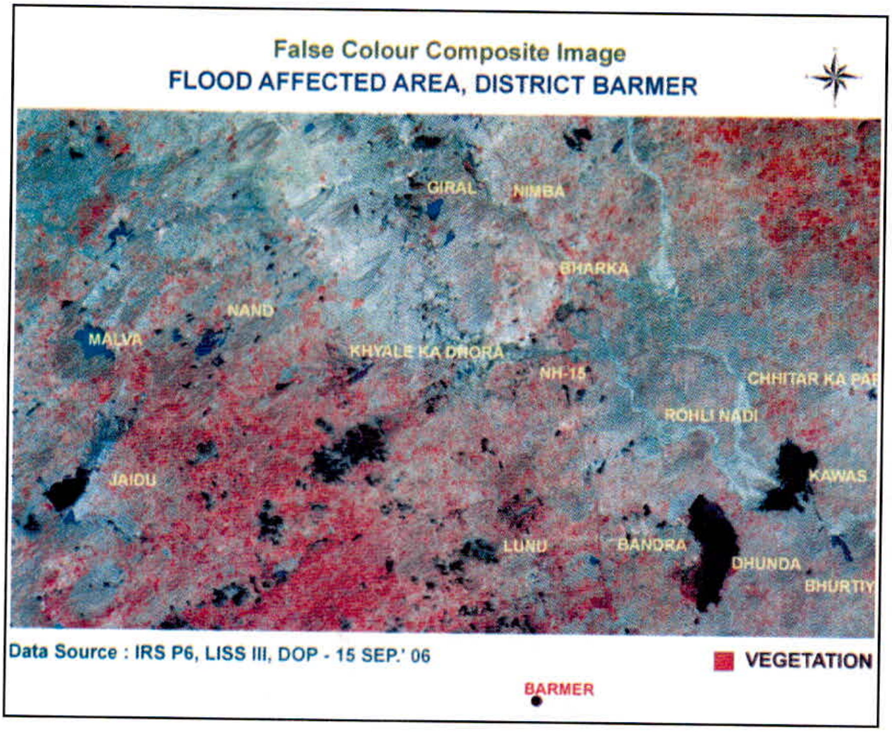


Fig. 1: Flood affected area in Barmer district as seen from satellite image

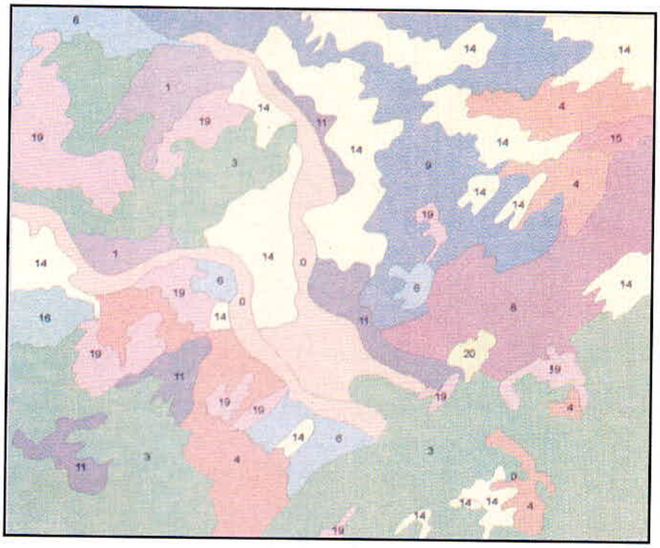


Fig. 2: Soil and land capability map of Kawas and adjoining area

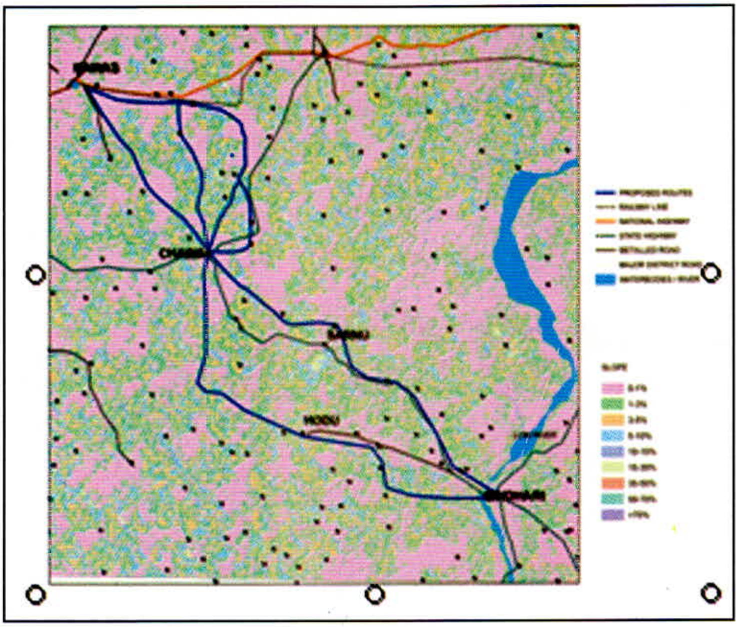


Fig. 3 : Proposed Path for Draining out Water to Luni

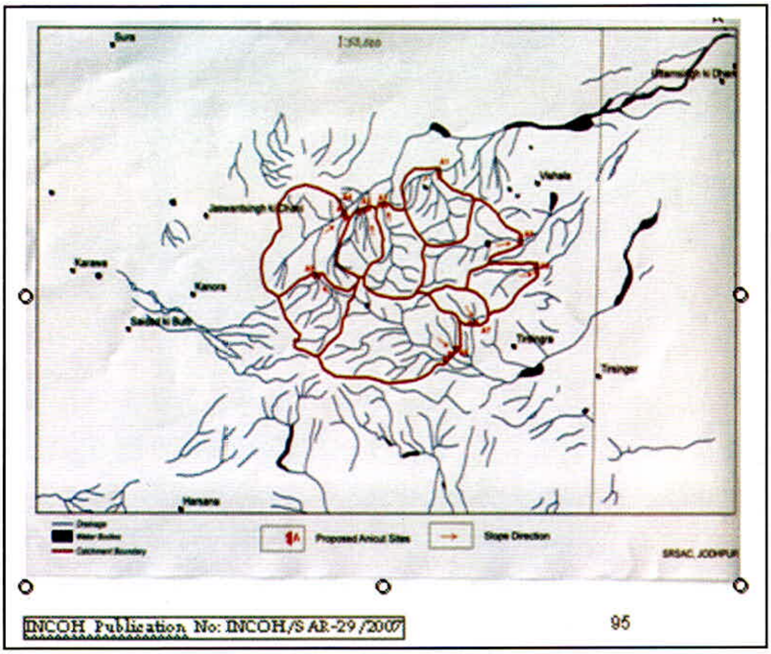


Fig. 4 : Proposed anicut sites

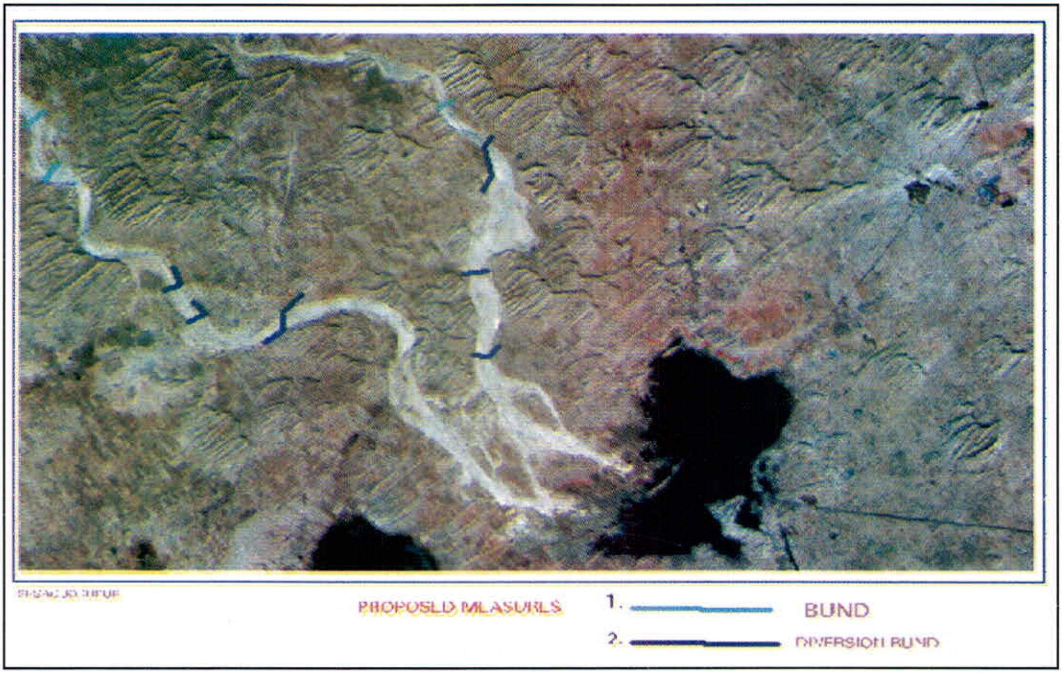


Fig. 5 : Site for Diversion Bunds

Flood Mitigation Efforts in Western Rajasthan: An Integrated Approach

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Former Head of Division
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Western Rajasthan is not only a drought prone region, it is also a victim of flood disaster from time to time. Recently during the year 2006, flood disaster occurred in various villages of Barmer district of western Rajasthan. All the communities of affected villages are the serious victim s of this flood disaster tragedy. Though it is chiefly a natural phenomenon, yet disaster mitigation efforts should be mainly focussed on reducing vulnerability of the area and the victims in the plan of disaster mitigation efforts. Since the case studies , that document local experience are rare, the focus should be on bringing out fresh, local and exploratory and experienced based materil for the purpose.

Flood disaster mitigation efforts should be focussed on the following aspects also:

Capacity Raising

While efforts are taken at understanding the nature and extent of vulnerability of the area and the communities, building capacity to reduce vulnerability remains mostly an area of darkness. Starting from rethinking vulnerability of the communities and reviewing the regional and local trends in its reduction, there is need define capacity building roles of the Government and non- Government Organisations (NGOs) and social workers; identify crucial factors for their effectiveness, list capacity enhancement needs and explore long term needs for vulnerability reduction. How such local capacity can ensure effective relief delivery and measure its performance? And what role media can play in this?

Institutional Assets

What are the institutional assets in the region, how adequate they are, what is the range, what arrangements they have with each other, and what processes they go through to increase their effectiveness as well as their accountability? And what about the limitations of response in building victim or survivor owned and managed mitigation organizations? Are there institutional arrangements in place so as to continuously improve the quality of relief and rehabilitation effprts? How can media strengthen such institutions?

Impact Assessment

In addition to above, there is need to bring out a realistic situation at the grassroots level, effects on settlements, land use crops grown, livestock, grazing lands, livestock migration, nature and extent of communities suffered, etc.

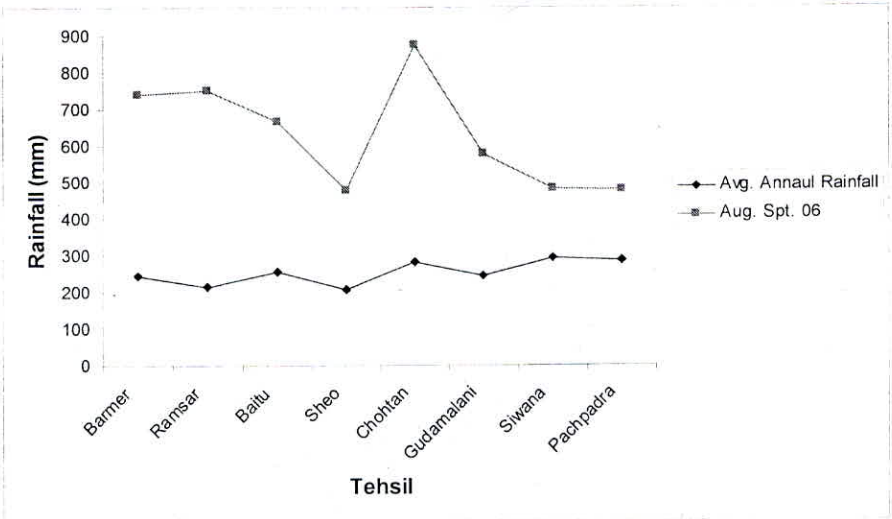
अतिवृष्टि के बाद मृदा का समुचित प्रबन्ध व सुझाव

डॉ0 प्रदीप पगारिया
कृषि विज्ञान केन्द्र (श्योर), दांता
बाड़मेर (राजस्थान)

पश्चिमी राजस्थान के शुष्क क्षेत्र में मानवीय आवास एवं भूमि का बहुत पुराना इतिहास है। कृषि जलवायु में अनुकूलित फसल किस्मों का उपयोग, वर्षा के अनियंत्रित वितरण के प्रभाव का सामना करने के लिए भिन्न फसलें उगाना एवं समय से पूर्व या अत्यधिक देर से मानसून आने पर उसके अनुसार फसलों का चयन पीढियों से अर्जित अनुभव इस क्षेत्र के निवासियों की अत्यन्त विकसित प्रकृति में स्पष्ट रूप से झलकता हैं।

किन्तु इस वर्ष बाड़मेर–जैसलमेर जिले में माह अगस्त 2006 में हुई अतिवृष्टि ने पुराने सभीं रिकार्ड तोडकर इस व्यवहार को बदल दिया हैं। इस क्षेत्र के इतिहास में पहली और वर्ष की सबसे भयंकर त्रासदी के रूप में बाढ के हालात इतने दयनीय हो गये कि बायतु, शिव व बाडमेर ब्लॉक के बहुत गॉव इससें पूरी तरह तबाह हो गये ।

Monsoon Chronological Scenario



बाढ के पानी का मार्ग

अतिवृष्टि ने इस बार पूरे जिले मे भंयकर त्रासदी मचाई परन्तु जहॉ पर सबसें भयंकर

Tehsil	Avg. Annual rain	Rain (Till 18th Aug., 06)	Rain Aug., 06						25-31 Aug	1-15 Sep.	Total
			19	20	21	22	23	24			
Barmer	245.0	215.0	40	80	135	171	22	15	00	64	742
Ramsar	214.2	206.0	02	50	55	214	73	21	02	129	752
Baitu	257.2	233.0	28	164	129	63	08	04	00	37	666
Sheo	207.2	102.0	12	44	130	125	12	07	05	39	476
Chohtan	282.0	344.0	28	53	98	70	25	43	01	211	873
Gudamalani	245.4	235.0	15	86	68	60	07	23	01	83	578
Siwana	294.2	274.0	27	91	30	12	02	07	07	33	483
Pachpadra	285.0	160.0	22	150	80	17	03	05	00	40	477
Average	277.0										631

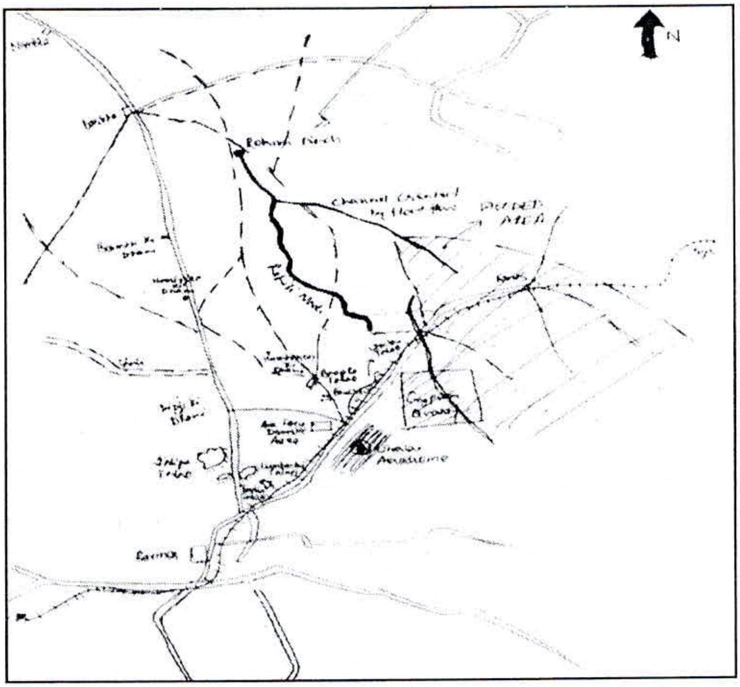
त्रासदी हुई और जहाँ पर बाढ़ का पानी आज दिन तक जमा हुआ है वहाँ पर पानी आने का मार्ग निम्न प्रकार रहा :–

क.स.	मार्ग	प्रभावित गाँव	दूरी .कि.
1.	1	मोती का गाला, खुडाल, बलाई, जोरानाडा, मोतीनाडा, परागणियों की ढाणी, चौंखला, खानजी का तला, छीतर का पार से कवास	186.7
2.	2	जुनेजों की बस्ती, जालेला की ढाणी, आगोरियो, निम्बला, कानीजों का तला से कवास	115.4
3.	3	विशाला, सोनार, कुम्भारों की ढाणी, सर का पार से कवास	109.4

बाढ़ के कारण

बाढ़ आने के मुख्यतयाः कारण

1. अतिवृष्टि जैसलमेर व उत्तरी भाग बाडमेर जिला
2. ढाल (Gradient/Slope)
3. पुराने पानी के मार्ग का पुनः प्रकट होना (Revival of old Water channel)



बाढ़ का पानी जमा होने के कारण

1. Low Lying Area
2. Un-developed and poor drainage
3. Sand dunes as Barrier
4. Presence of non-permeable strata of Gypsum and Bentonite

बाढ़ से क्षति

मुख्य क्षति निम्न हैं :–

1. अतिवृष्टि / बाढ से बाडमेर जिले के 8 लाख लोग प्रभावित हुए।
2. 140 गाँव के आस–पास लोग अकाल मुत्यु के शिकार हो गये।
3. 80 हजार के लगभग पशुधन की क्षति हुई।
4. 36 जिप्सम की फैक्ट्रीयाँ पूरी तरह पानी में डूब गईं।
5. लगभग 5200 मकान ढह गये।

कृषि की दृष्टि से क्षति

1. 30 करोड़ की फसल तबाह हुई ।
2. 4 लाख हैक्टेयर क्षेत्र में पानी का तेज बहाव ।
3. लाखों बीघा उपजाउ जमीन खराब ।

सर्वेक्षण तकनीक

बाडमेर व जैसलमेर जिले में अगस्त 2006 में हुई अतिवृष्टि ने भारी तबाही मचाई तथा बहुत जन व धन की हानि हुई । इस अतिवृष्टि से बाड़मेर, बायतु व शिव ब्लाकों को मिलाकर लगभग 80 गॉव बहुत ज्यादा प्रभावित हुए जिसमें से कृषि की दृष्टि से 57 गॉव बहुत बुरी तरह से प्रभावित हुए । इन 57 गॉवों का सर्वे कर हर गॉव से 20 मृदा व सिंचाई जल के नमूने इकट्ठे किये गये । उन नमूनों का मृदा एवं सिचांई जल परिक्षण प्रयोगशाला कृषि विज्ञान केन्द्र श्योर, बाडमेर में विस्तृत जाँच की गई उसके आधार पर उचित सुझाव व प्रबन्ध किया गया

अतिवृष्टि के बाद कृषि की स्थिति

अतिवृष्टि से खरीफ 2006 की फसलो का तो नुकसान हुआ ही है परन्तु लगभग 1990 हैक्टर में किसानों ने अतिवृष्टि से जमा पानी से रबी 2006 में पम्प व अन्य साधनों द्वारा सिंचाई करके प्रथम बार अच्छी फसल उत्पादन प्राप्त किया हैं जिसमें मुख्यत: जीरा, इसबगोल, रायडा, चना आदि फसलें ली हैं अतिवृष्टि के बाद मृदा की मुख्यता: चार स्थिति उत्पन्न हुई

1. क्ले या Sedimentation जमा ।
2. खेत में बड़े–बड़े गड्डे (Ravines) हो गए ।
3. मृदा जमा हो गई ।
4. मृदा अपरदन हो गया ।

उपरोक्त मृदा की स्थिति को देखते हुए वर्तमान के हालात में फसल उत्पादन लेना और होना असंभव हैं। अगर कृषि करनी है तो उसको पहले कुछ सुधार एवं प्रबंध तकनीक काम में लानी पड़ेगी औंर उसके बाद फसल उत्पादन प्राप्त कर सकता हैं।

1. क्ले या Sedimentation जमा हो गए।

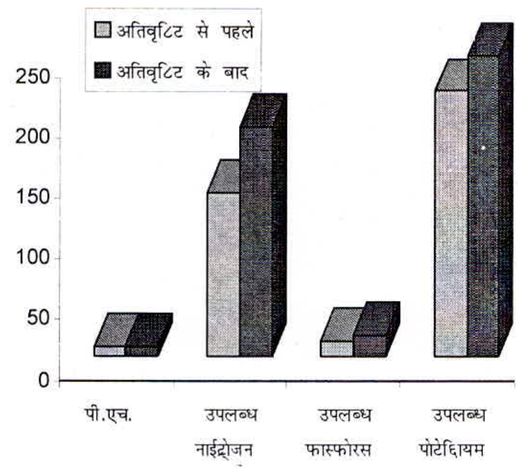
ऐसी स्थिति वहाँ पर देखने को मिली जहाँ पर भी थोडे दिन अतिवृष्टि का पानी जमा रहा हैं। वहाँ पर चिकनी मिट्टी की बड़ी–बड़ी पपडीया जमा हो गई हैं । जिसे क्ले या sedimentation का जमा होना कहते हैं । वर्तमान में बिना कुछ प्रबन्ध क्रियाए कियें ही खेती असभंव हैं या उत्पादन बहुत ही कम या नगण्य के बराबर होने के आसार हैं । जो क्ले या Sedimentation जमा हुए हैं उसका उचित तरीकें से उपयोग/प्रबंध करकें अच्छा फसल उत्पादन प्राप्त कर सकता हैं क्योंकि यहाँ की मृदा बालू है उसमें पौशक तत्व व जल धारण क्षमता बहुत कम होती हैं । अगर यह क्ले बालू मृदा में मिल जाएगी तो मृदा की जल धारण क्षमता बढ सकती हैं तथा पौषक तत्व भी पौधों को ज्यादा मिल जायेंग, जिससें फसल उत्पादन में भी वृद्धि होगी । इस प्रकार की क्ले 1' से लेकर 3' फीट तक जमा हैं । मृदा में भौतिक व रसायनिक गुणों में परिवर्तन देखने को मिला । अतिवृष्टि से पहले मृदा में रसायनिक गुणों की मात्रा निम्न प्रकार थी :–

पी.एच., जैविक कार्बन, फास्फोरस, उपलब्ध नाईट्रोजन व पोटेशियम की मात्रा निम्न प्रकार थी क्रमशः 7.8 से 9.1 प्रतिशत, 0.03 से 0.111 प्रतिशत, 5.0 से 21, 90 से 180 व से 60 से 280 किग्रा प्रति हैक्टर थी। ऐसी मृदा में क्ले / Sedimentation जमा हो गये औंर ये क्ले / Sedimentation की वजह से मृदा की उर्वरता शक्ति में सुधार हुआ हैं। अतिवृष्टि के बाद मृदा के रासायनिक गुणों में निम्न स्थिति हों गई । मृदा के पी.एच. मान को 0.3 से 0.5 तक की कमी देखी गई। जैविक कार्बन में तीन–चार गुना वृद्धि हुई तथा साथ ही उपलब्ध नाइट्रोजन, फास्फोरस व पौटेशियम की मात्रा में अतिवृष्टि से पहले की तुलना में एक–दो गुना वृद्धि देखी गई।

मृदा गुण

क.स.	परिमाप	अतिवृष्टि से पहले	अतिवृष्टि के बाद
1	पी.एच. (1:2)	7.8 - 9.1	7.5 - 8.6
2	जैविक कार्बन (%)	0.03 - 0.111	0.09 - 0.473
3	उपलब्ध नाईट्रोजन (कि. ग्रा. प्रति हैक्टर)	90 - 180	120 - 260
4	उपलब्ध फास्फोरस (कि.ग्रा. प्रति हैक्टर)	5.0 - 21.0	9.0 - 27.0
5	उपलब्ध पोटेशियम (कि. ग्रा. प्रति हैक्टर)	160 - 280	210 - 320

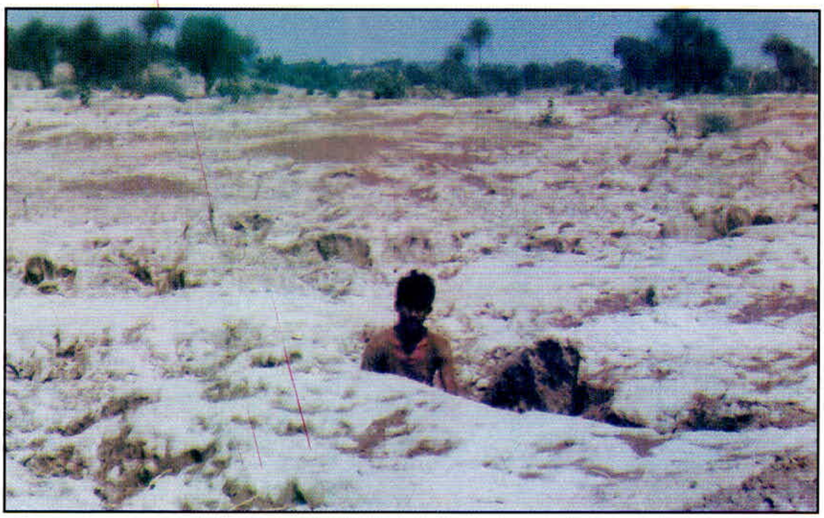
'तालिका में इक्ट्ठे किए गए नमूने का औंसत मान दिया गया है



परिमा प

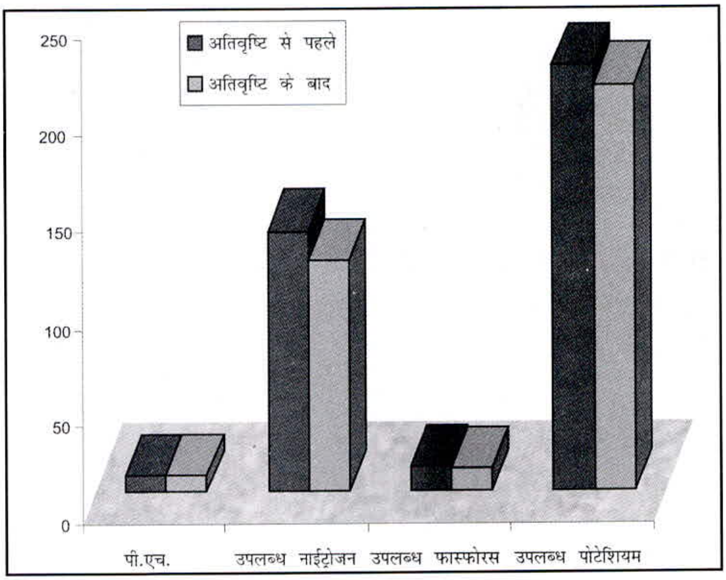
2. खेत में बड़े–बड़ें गड्डें हो (Ravines) जाए

ऐसी स्थिति उस खेत में देखने को मिली जहाँ पर भी अतिवृष्टि का पानी एक नाले या नदी के रूप में गुजरा हैं जिस खेत से भी पानी गुजरा हैं वो पानी अपने साथ खेत की मृदा लेकर चला गया तथा पीछे उस खेत में बड़े–बड़े कठोर खड्डें बना दिए तथा मिट्टी की बहुत ज्यादा सख्त हालात बना दें। जिस पर वर्तमान में खेती करना नामुमकिन है और ऐसी स्थिति अधिकतर शिव तहसील मे देखने को मिली। इस प्रकार के गड्डे 1/2'' से लेंकर 5'' तक हुए हैं। ऐसे मृदा के भौतिक व रासायनिक गुणो मे परिवर्तन आया हैं। यह परिवर्तन निम्न प्रकार हैं।



मृदा गुण

क.स.	परिमाप	अतिवृष्टि से पहले	अतिवृष्टि के बाद
1	पी.एच. (1:2)	7.8 - 9.1	7.7 - 9.3
2	जैविक कार्बन (%)	0.03 - 0.111	0.03 - 0.09
3	उपलब्ध नाईट्रोजन (कि.ग्रा. प्रति हैक्टर)	90 - 180	90 - 150
4	उपलब्ध फास्फोरस (कि.ग्रा. प्रति हैक्टर)	5.0 - 21.0	5.0 - 19.4
5	उपलब्ध पोटेशियम (कि.ग्रा. प्रति हैक्टर)	160 - 280	160 - 260

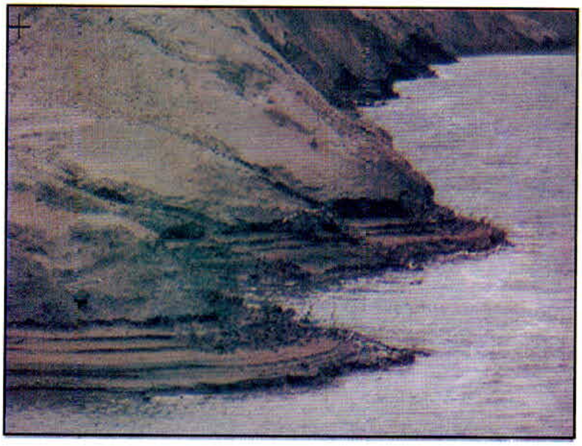


3, मृदा जमा हों गई

जिस खेत में से भी नदी या नाले के रूप में पानी का प्रवाह हुआ वह पानी अपने साथ उन खेतो की मृदा लेकर गया और उस मृदा को कही ओर जगह जमा कर दिया जिससे समस्याजनक स्थिति पैदा हो गई । रेत जमा होने के कारण उर्वरा मृदाए ढक गई तथा अन्य उर्वरा मृदा आ गई जिससे वर्तमान परिस्थितियो में खेती करना दुर्लभ है क्योंकि जो मृदा जमा हुई है उस मृदा के कण बहुत बड़े–बड़े हैं तथा वह मृदा बजरी प्रकार की हैं। और इस प्रकार की मृदा की जल धारण क्षमता बहुत ही कम है तथा फसल उत्पादन के लिए आवश्यक पौषक तत्व भी नगण्य हैं ।

इस प्रकार की स्थिति जालिला व सूवाला उसके आस पास के गॉवो में ज्यादा है जहाँ पर रेत 1/2 फिट से लेकर 4 फिट तक जमा है । इस प्रकार की मृदा के रसायनिक गुणों

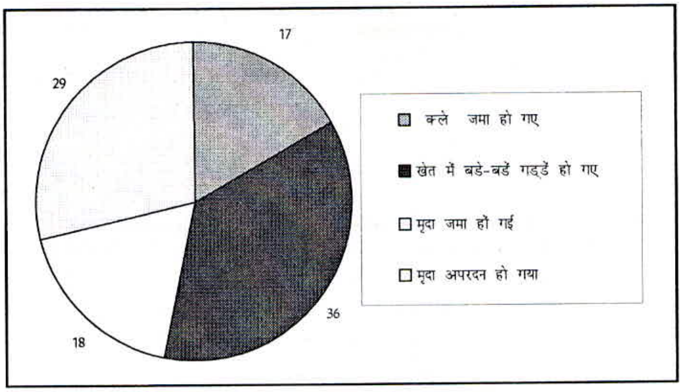
में निम्न परिवर्तन प्रकार देखने को मिला – मृदा के पी.एच. मान में 0.2 से 0.4 तक की कमी हुई। जैविक कार्बन, नाइट्रोजन, फास्फोरस व पोटेशियम में कमी देखने को मिली, ऐसी परिस्थिति में वर्तमान में खेती संभव नहीं है।



4, मृदा अपरदन हो गया

जिस खेत में से भी नदी या नाले के रूप में पानी का प्रवाह हुआ वह पानी अपने साथ उन खेतों की मृदा को लेकर गया और पीछे छोड गया कंकड, पत्थर। ऐसी स्थिति शिव ब्लाक मे ज्यादा देखने को मिली । ऐसे खेतों में वर्तमान में तो क्या आने वाले 3–4 सालों में भी कुछ भी उत्पादन संभव नहीं हैं । क्योंकि फसल उत्पादन के लिए मृदा एक प्रमुख अवयव है। मृदा के रसायनिक गुणों में परिवर्तन देखने को मिला। जैविक कार्बन, नाइट्रोजन, फास्फोरस व पोटेशियम में कमी देखी गई ऐसी स्थिति में वर्तमान में फसल उत्पादन संभव नहीं हैं।

अतिवृष्टि के बाद मृदा की स्थिति



अतः इन समस्या से छुटकारा पाने के लिए निम्न कृषण कियाएं करनी चाहिए :–

1. जिस खेत में अतिवृष्टि का पानी जमा हुआ है वहाँ पर क्लें / Sedimentation जमा हुए हैं उस खेत में पहले Discplough/ Harrow/ Plough से मृदा को पलटी मार दें। पल्टी मारने के बाद उस खेत में कल्टी–वेटर चला दे

2. जिस खेत में पानी का प्रवाह ज्यादा रहा वहाँ पर ऐसी स्थिति देखने को मिली उस खेंत में ट्रैक्टर द्वारा Plough चलाकर खड्डें कों भर कर जमीन समतल करे। खड्डे भरने के लिए आस पास से मिट्टी डाले। ऐसी भूमि पर हरी खाद उगाकर पलटे। इससें मिट्टी की सरंचना व उर्वरकता में सुधार होगा ।

3. जिस खेत में मृदा जमा हो गई बरसात के पहलें खेत को छोटे–छोटें भागों में बाटंकर मजबूती से मेड़बंदी करें जिससे बरसात का पानी इसमें भरा रह सके जिससें मृदा के भौतिक गुणों में परिवर्तन हो सके । वहाँ पर अगर होल तकनीक द्वारा पौधों को लगाना चाहिए तथा जिससे मृदा सरंक्षण में मदद मिल सके ।

4. जिस खेत में कंकड, पत्थर निकल गए वहॉ पर डेयरी वाली या नाडी वाली मृदा बालू मृदा के साथ उचित मात्रा में मिलाकर डाले । इससें पहलें जो मृदा खेत में मिलाई जा रहीं हैं । उसका प्रयोगशाला में परीक्षण करा लेवे।

5. खेत में फसल बोने से पूर्व सड़ी हुई गोबर की खाद, कम्पोष्ट, वर्मीकम्पोष्ट, आदि का 4–5 टन प्रति हैक्टर का प्रयोग करें ।

6. फसल विशेष के अनुसार खाद एवं उर्वरक का प्रयोग करें ।

इन उपरोक्त विधियों को समन्वित कर सुनियोजित पद्वति के रूप में काम में लाकर अधिकतम लाभ प्राप्त किया जा सकता हैं। अन्यथा बिना प्रबन्धन में कुछ भी उत्पादन ले पाना असभंव हैं ।

Recommendations

Different papers have covered monsoon scenario of the year 2006, causes of flood and water pounding and remedial measures to over come the complex problem. The devastating flood situation in Barmer (August 2006) was mainly due to high intensity of rainfall occurred continuously for three days. Since the soil column of flood affected soil was already saturated through the preceding rains, there was no infiltration of rain water. Suggestions have been made to make efficient use of pounded water for irrigating rabi crops, developing grasslands, silvipastures, sand dune stabilization and ground water recharge.

The seminar was very much effective because such a multidisciplinary gathering to discuss the issue was not arranged earlier on this topic. The seminar has brought out many recommendations which can directly be applied in the field. Through the satellite remote sensing the source of flood water and causes of water impounding could be ascertained and suggestions for management of floodwater and preventive measures could be suggested. The remote sensing technology also showed way to drain the water in natural streams. The precious water in the desert should be utilized for irrigating rabi crops, raising trees and shrubs on wastelands and sand dune stabilization. Specific recommendations are listed below.

- ✓ There is an urgent need to develop meso-scale models. For this purpose Rajasthan is entirely different from rest of the country because there is large spatial and temporal variation which it requires a closer network of automatic weather stations. Meteorological stations should be strengthened/established in all districts of Rajasthan, which will help in better prediction of the weather.
- ✓ There is a need to strengthen the existing weather forecasting facility and to establish a separate unit under the National Rainfed Authority of Government of India for long term rainfall forecast in the arid zone.
- ✓ The major cause of devastating flood situation in Barmer (August 2006) was mainly due to high intensity of rainfall occurred continuously for three days. Since the soil column of flood affected soil was already saturated through the preceding rains, there was no infiltration of rain water. Proper drainage facility needs to be created in this area.
- ✓ As preventive measures concerned departments may form core groups to visit the flood affected areas and suggest the people regarding possible spread of diseases in human beings and suggest preventive measures.
- ✓ To prevent spread of diseases like Foot and Mouth, Hemorrhagic Septicaemia, Anthrax, etc. mass scale vaccination should be undertaken in animals.
- ✓ Flood water may be used for irrigating rabi field crops, horticultural crops, pasture and grazing lands.
- ✓ After receding /removal of water the land may be used for planting cucurbits/fodder/

short duration summer crops like moong, moth, guar, etc.

- ✓ Detailed investigations are needed on effect of floods on wild life/flora/fauna mainly rodents, changes in faunal bio-diversity, effect on natural food web (prey predator aspects), breeding profiles of native fauna and risk of rodent borne diseases in the area.
- ✓ Flood water could be used for recharging the ground water

The proposed short term measures are:

- ✓ Sand dune stabilization under Drought Combat Project.
- ✓ Re-drain Water and Check the drain through bunds.
- ✓ Provide interest free loan to farmers along with fertilizer and seeds on subsidized rates.

The proposed long term planning for flood prevention are:

- ✓ Vegetation barriers against slope along stream course.
- ✓ Diversion bunds across stream course, preferably near open scrub/ waste lands so that spreading water does not cause damage to cultivated areas.
- ✓ Excavation of ponds/ *nadies* in wasteland with gentle slope.
- ✓ Peripheral bunds along periphery of villages.
- ✓ Vegetation cover is recommended (Grasses/ Shrubs along bunds of existing water harvesting structures- *nadis, khadins*).
- ✓ Rehabilitation of mining and gypsiferous areas by Silvi-pasture areas.
- ✓ Shifting of habitations to elevated locations.
- ✓ Open drain linking to natural streams.
- ✓ *Capacity building*: There is need to develop capacity building of Government and NGOs and social workers for tackling natural disasters.
- ✓ *Institutional assets*: Institutions should be identified in the region who can impart training and create assets for fighting natural hazards.

INDIAN NATIONAL COMMITTEE ON HYDROLOGY (INCOH)

(IHP National Committee of India for UNESCO)

Constituted by the Ministry of Water Resources in 1982

INCOH Activities Related to UNESCO's IHP-VI Program

India is actively participating in IHP-VI activities and detailed program has been chalked out in accordance with IHP-VI themes towards preparation of reports, taking up research studies, organization of seminars/symposia at national and regional level, and promotion of hydrological education in the country. India, actively participated in all the relevant and feasible programs identified under the various focal areas of IHP-VI themes as given below.

India's participation in IHP-VI program

Theme	Selected Focal Area
1. Global Changes and Water Resources.	Integrated assessment of water resources in context of global land based activities and climate change.
2. Integrated Watershed and Acquifer	Extreme events in land and water resources Dynamics
3. Land Habitat Hydrology	Dry lands
4. Water and Society	Raising public awareness on water interactions
5. Water Education and Training	Continuing education and training for selected target groups

Further. Ministry of Water Resources, Government of India is looking for the following activities to be taken up for IHP-VII program of UNESCO scheduled during 2008-2013:

India's participation in IHP-VII program

Theme	Primary Focal Areas	Activities to be taken up
I: Global Change, Watersheds and Aquifers	I-1: Large-scale groundwater dependencies related to global change.	Artificial recharge of water and groundwater assessment
	I-2: Hydrological extremes in sensitive and stressed biomass and hydro climatic zones e.g. small island developing states.	Water resources management under drought situation
	I-3: Global change and feedback mechanism of hydrological processes in stressed environments.	Assessment of water resources under climate change
II: Ecohydrology and Environmental Sustainability.	Risk based environmental management (under uncertainty), especially climate change threats to ecosystem functions.	1. Real time flood forecasting 2. Flood inundation zoning for different return periods.
III: Water Quality, Human Health and Food Security	Access to safe water, human health and integrated water resource management.	International conference on water, environment, energy and society (WEES

INCOH Publications

Publications of Jalvigyan Sameeksha Journal

To disseminate information and promote hydrological research in the country, INCOH brings out the Journal entitled "Jal Vigyan Sameeksha (Hydrological Review Journal)". The papers published in the Journal are by invitation only. The Journal is widely circulated amongst major organizations and agencies dealing in water resources.

State-of-Art Reports

In pursuance of its objectives to periodically update the research trends in different branches of hydrology, state of art reports authored by experts identified by INCOH from various institutes and organizations in India , are published regularly. These reports are circulated free of cost to central –IX and state government agencies including academic and research organizations.

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