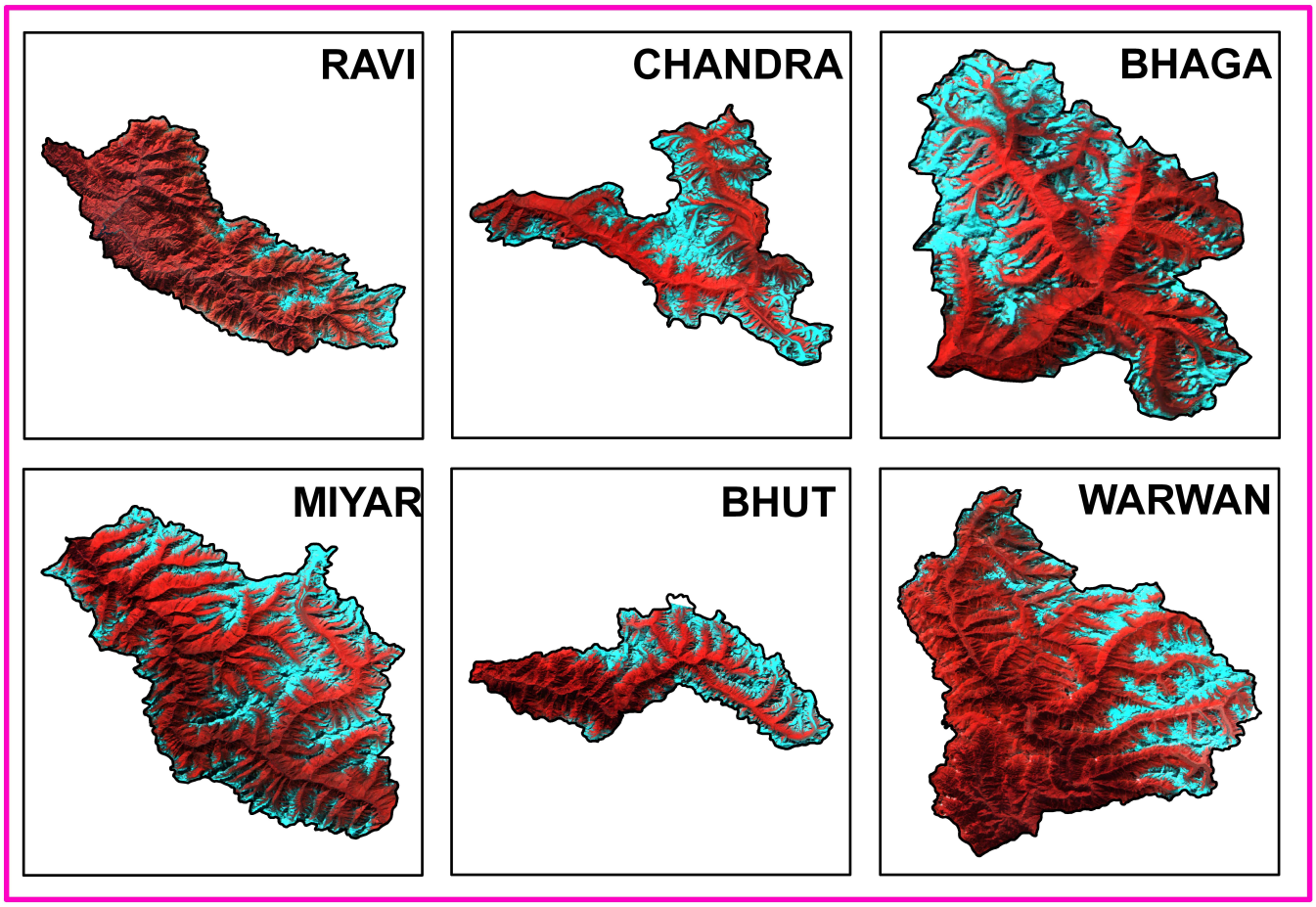
SNOW COVER ATLAS OF CHENAB BASIN

Sub basins: Ravi, Chandra, Bhaga, Miyar, Bhut and Warwan

(A Joint Project of Indian Space Research Organisation and Ministry of Environment and Forests, Govt. of India)

Year : 2012-13



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Abstract	This atlas gives subbasin-wise distribution of snow cover in the Chenab basin from October 2012 to June 2013. The subbasins included in this report are Ravi, Chandra, Bhaga, Miyar, Bhut and Warwan. The areal extent of snow cover was estimated in fully automatic mode using Normalized Difference Snow Index (NDSI) based algorithm. For this purpose AWiFS sensor of Resourcesat satellite was used. This atlas gives snow cover products, statistics and seasonal snow depletion curve. It is expected that this data will be useful for hydrological and climatological applications.
Key words	Snow cover, NDSI, AWiFS, depletion curve, Ravi, Chandra, Bhaga, Miyar, Bhut and Warwan basins.
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CONTENTS

1. **Introduction**

Snow covers almost 40 per cent of the Earth's land surface during Northern Hemisphere winter. This makes albedo and areal extent of snow as important component of the Earth's radiation balance (Foster and Chang, 1993). In addition, large areas in the Himalayas are also covered by snow during winter. Area of snow can change significantly during winter and spring. This can affect stream flow for rivers originating in the higher Himalayas. All the rivers originating from higher Himalayas receive almost 30-50 % of annual flow from snow and glacier melt run off (Agarwal et al., 1983). In addition, snow pack ablation is highly sensitive to climatic variation. Increase in atmospheric temperature can influence snowmelt and stream runoff pattern (Kulkarni et al., 2002). Therefore, mapping of the areal extent and reflectance of snow are important parameter for various climatological and hydrological applications. In addition, extent of snow cover can also be used as input for numerous other applications.

Mapping and monitoring of seasonal snow cover using field methods are normally very difficult in a mountainous terrain, like the Himalayas. Therefore, remote sensing techniques have been extensively used for snow cover monitoring. Snow cover monitoring using satellite images were started by using the TIROS-1 satellite from April 1960 (Singer and Popham 1963). Since then, the potential for operational satellite-based mapping has been enhanced by the development of higher temporal frequency and satellite sensors with higher spatial resolution. In addition, satellites with better radiometric resolutions, such as NOAA have been used successfully for snow mapping (Hall et al., 1995). This is possibly due to the distinct spectral reflectance characteristics of snow in visible and near infrared regions. India has launched series of Indian Remote Sensing satellite (IRS) to study the different earth resources. Previously launched satellites have flown with many sensors having different spatial, temporal and spectral resolutions. Recently launched RESOURCESAT-1 satellite has three different sensors namely LISS III, LISS IV & AWiFS with different spatial, temporal and spectral resolutions as desired for different applications. AWiFS (Advanced Wide Field Sensor) is an advanced version of earlier Indian satellite sensor WiFS (Wide Field Sensor) with improved spectral and spatial resolutions maintaining the same repetivity. There are a series of other polar orbiting satellites, like Landsat, NOAA and MODIS etc., which have provided information on different aspects of

snow. Geo-stationary satellites also proved their utility in mapping/monitoring the snow-covered regions. Information generated from satellite observations has been extensively used for snowmelt runoff modeling (Kulkarni et al., 1997).

2. Study Area:

This Atlas gives distribution of snow cover in six subbasins of the Chenab basin. These are Ravi, Chandra, Bhaga, Miyar, Bhut and Warwan sub basins. Locations of these basins are shown in Figure 1.

3. Data used:

AWiFS data from October 2012 to June 2013 were used in this study.

4. Normalised Difference Snow Index (NDSI):

In general, the reflectance of snow is high at the red end of the visible spectrum. It tends to decline in the near-infrared region until 1090 nm, where slight gain in reflectance occurs and gives a minor peak at approximately 1090 to 1100 nm. One of the important difficulties in snow cover monitoring is the presence of cloud cover. Cloud has strong reflectivity in visible, NIR and SWIR regions while snow absorbs in SWIR, and this difference can be utilized for snow/cloud discrimination. Normalized Difference Snow Index (NDSI) utilize the normalized ratio of green and SWIR and is used as an automated approach for snow mapping addressing the shadow and cloud problems in snow bound areas.

Normalized Difference Snow Index was calculated using the ratio of green wavelength (band 2) and SWIR (band 5) of AWiFS sensor:

$$Normalized\ Difference\ Snow\ Index(NDSI) = (band2 - band5)/(band2 + band5) \quad ..(1)$$

To estimate NDSI, DN numbers were converted into reflectance. This involves conversion of digital numbers into the radiance values, known as sensor calibration, and then estimation of reflectance from these radiance values. Various parameters needed for estimating spectral reflectance are maximum and minimum radiances and mean solar exo-atmospheric spectral irradiances in the satellite sensor bands, satellite data acquisition time, solar declination, solar zenith and solar azimuth angles, mean Earth-Sun distance etc. (Markham and Barker, 1987; Srinivasulu and Kulkarni, 2004).

5. Snow cover monitoring algorithm

An algorithm is developed to provide changes in the areal extent of snow (Kulkarni et. al., 2006). Snow extent is estimated at an interval of 5-days and 10-days, depending upon availabilities of AWiFS data. In 5-daily product, snow extent is generated scene-wise. In this product, snow and cloud extents are given. Estimate of cloud is important because, at times, snow is covered by cloud and this may be classified as non-snow area, leading to erroneous conclusions. In 10-daily product, three scenes are analyzed, if available. For example, 10 March product data of 5, 10 and 15 March was used. If any pixel is identified as snow on any one date then this pixel will be classified as snow on final product. This provides snow cover at an interval of 10 days, an important requirement in hydrological applications. Therefore, this product is generated basin-wise. Since this product is using three scenes, probability becomes high that at least in one scene, pixel may be cloud-free and this helps in overcoming problem associated with snow under cloud cover. If three consecutive scenes are not available, then all available scenes in 10 days window was used in the analysis. Differentiation between water and snow is difficult using NDSI image. In addition, separation of snow and water pixels is also difficult based on reflectance due to mountain shadow. Therefore, in the present algorithm, water bodies are marked in pre-winter

season and are masked in the final products during winter. Flow diagram of the algorithm is given in Figure 2.

6. Results and discussions

In this atlas, basin-wise snow cover statistics, maps, and seasonal depletion curves have been provided from October 2012 to June 2013. Snow ablation pattern varies from basin to basin, depending on area altitude distribution in the basins. Accumulation and ablation pattern in Chandra and Bhaga river basin is almost same and significant amount of melting was observed in early part of winter. From December to end of April almost entire basin is covered by snow for Chandra, Bhaga and ablation starts from the end of April. In the Bhut, Warwan and the Miyar sub-basins accumulation starts from mid of November and ablation starts from mid of March. In case of Ravi sub-basin no accumulation is found till mid of November then in the month of January, maximum snow was observed 86% and it reduces up to 49% in the beginning of March and ablation continuous till June.

Acknowledgements

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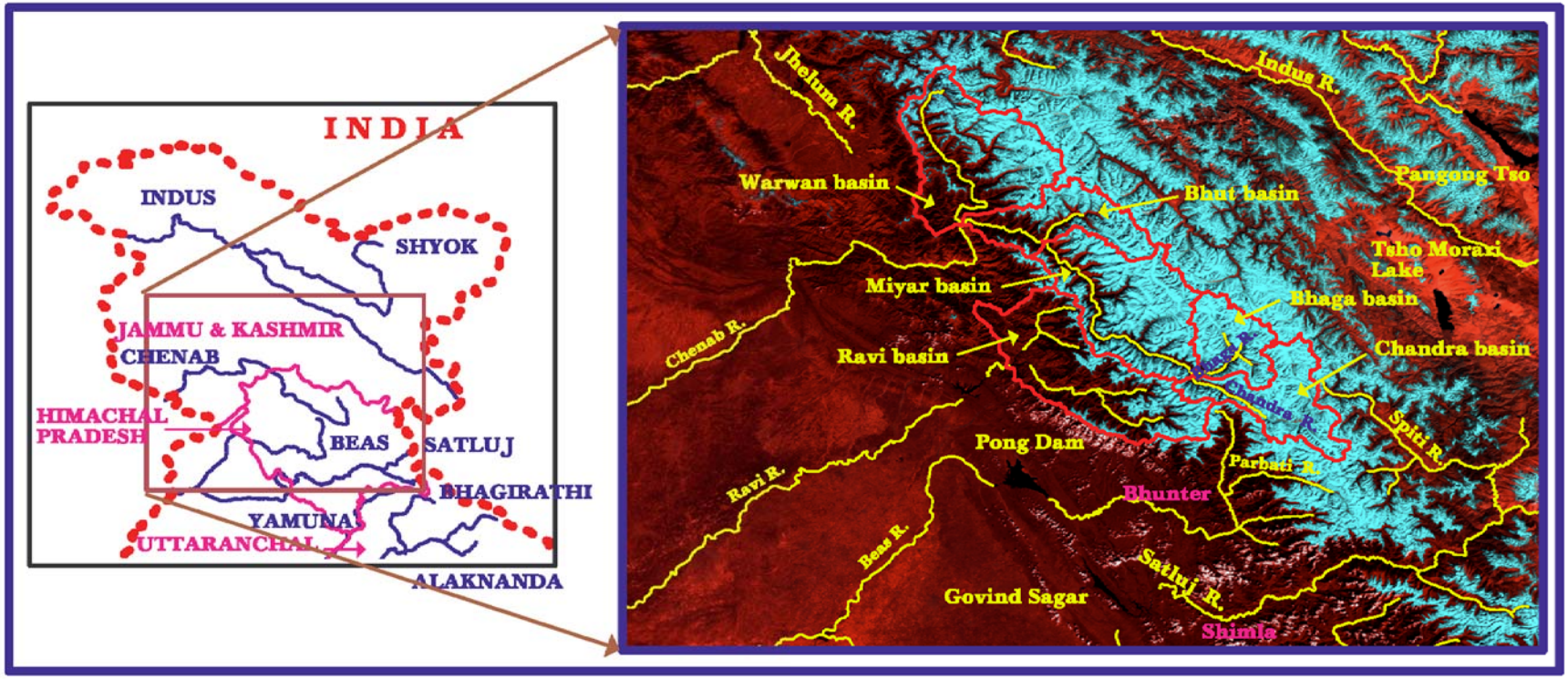


Figure 1: Location map of Ravi, Chandra, Bhaga, Miyar, Bhut and Warwan sub-basins (Part of Chenab basin)

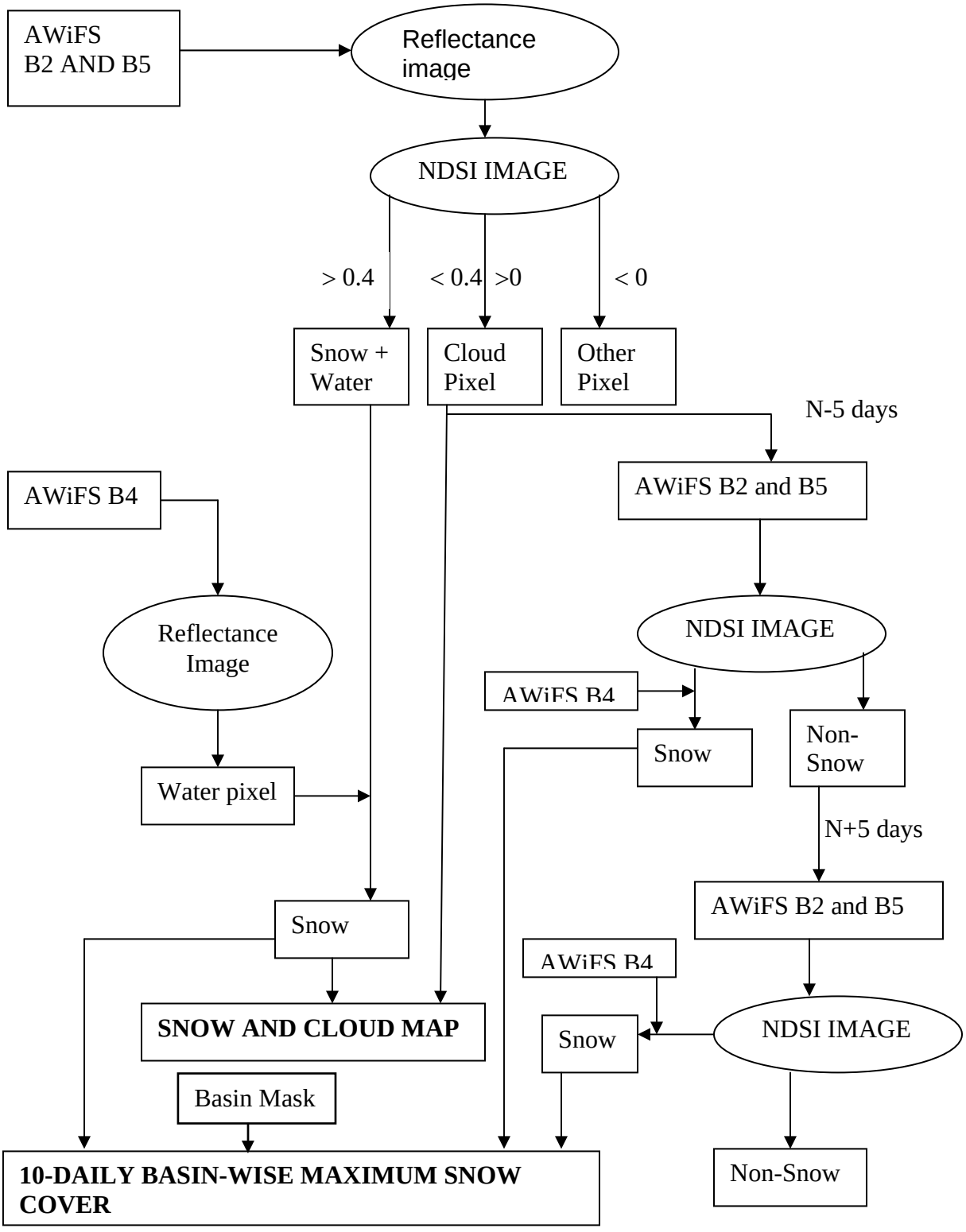


Figure 2: Algorithm for snow cover mapping using AWiFS data

RAVI BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: RAVI **BASIN AREA: 4907 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	2-Oct-12	451	9	6	21-Oct-12(C)	361	7
2	4-Oct-12	656	13	7	26-Oct-12	543	11
3	6-Oct-12	426	9	8	30-Oct-12	604	12
4	7-Oct-12	353	7	9	31-Oct-12	472	10
5	14-Oct-12	671	14				
November 2012							
10	4-Nov-12	458	9	14	12-Nov-12	523	11
11	6-Nov-12(C)	650	13	15	16-Nov-12	555	11
12	7-Nov-12	598	12	16	26-Nov-12	916	19
13	11-Nov-12	767	16	17	30-Nov-12	3462	71
December 2012							
18	1-Dec-12	2935	60	20	25-Dec-12	2489	51
19	17-Dec-12	3717	76	21	30-Dec-12	2576	53
January 2013							
22	3-Jan-13	2304	47	27	13-Jan-13	2871	59
23	6-Jan-13	1966	40	28	20-Jan-13	4236	86
24	8-Jan-13	2271	46	29	22-Jan-13	3869	79
25	10-Jan-13	2068	42	30	25-Jan-13	3124	64
26	11-Jan-12(C)	1483	30	31	30-Jan-13(C)	2985	61
February 2013							
32	1-Feb-13	2790	57	35	20-Feb-13	3179	65
33	6-Feb-13	1966	40	36	25-Feb-13	3179	65
34	8-Feb-13(C)	3772	77				
March-2013							
37	2-Mar-13	3121	64	41	19-Mar-13	2322	47
38	4-Mar-13	2764	56	42	21-Mar-13	2293	47
39	7-Mar-13	2622	53	43	26-Mar-13	2893	59
40	18-Mar-13	2396	49				
April 2013							
44	4-Apr-13	2395	49	47	12-Apr-13(C)	2986	61
45	5-Apr-13	2236	46	48	19-Apr-13	1925	39
46	11-Apr-13(C)	1356	28	49	24-Apr-13	1626	33
May 2013							
50	3-May-13	1629	33	52	15-May-13	1402	29
51	8-May-13	1320	27	53	20-May-13	1070	22

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
June 2013							
54	6-Jun-13(C)	909	19	56	11-Jun-13(C)	1745	36
55	8-Jun-13	569	12	57	22-Jun-13(C)	315	6

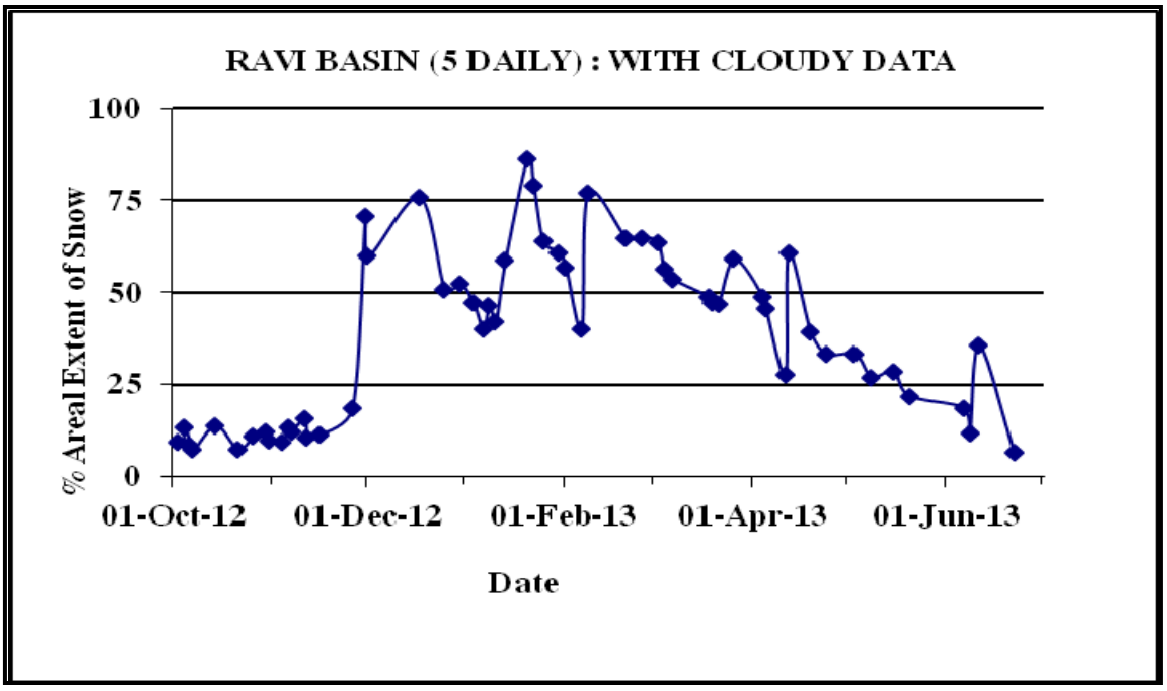
C = CLOUDY DATA

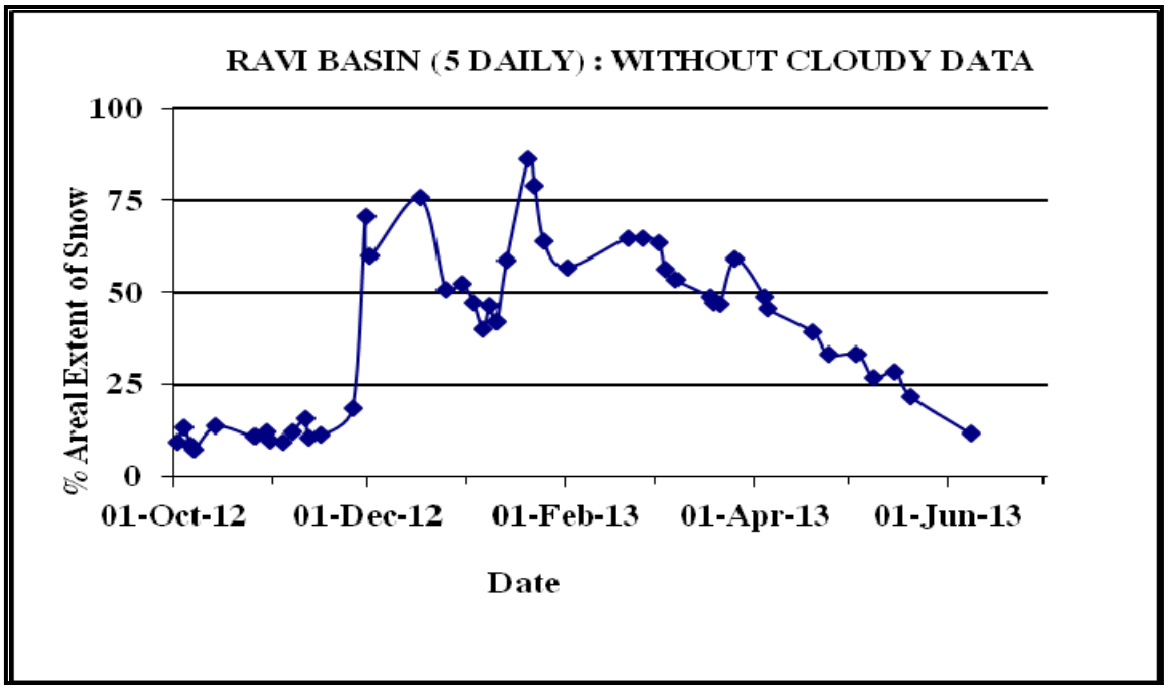
AREAL EXTENT OF SNOW (10-DAILY)

BASIN NAME: RAVI **BASIN AREA: 4907 sq km**

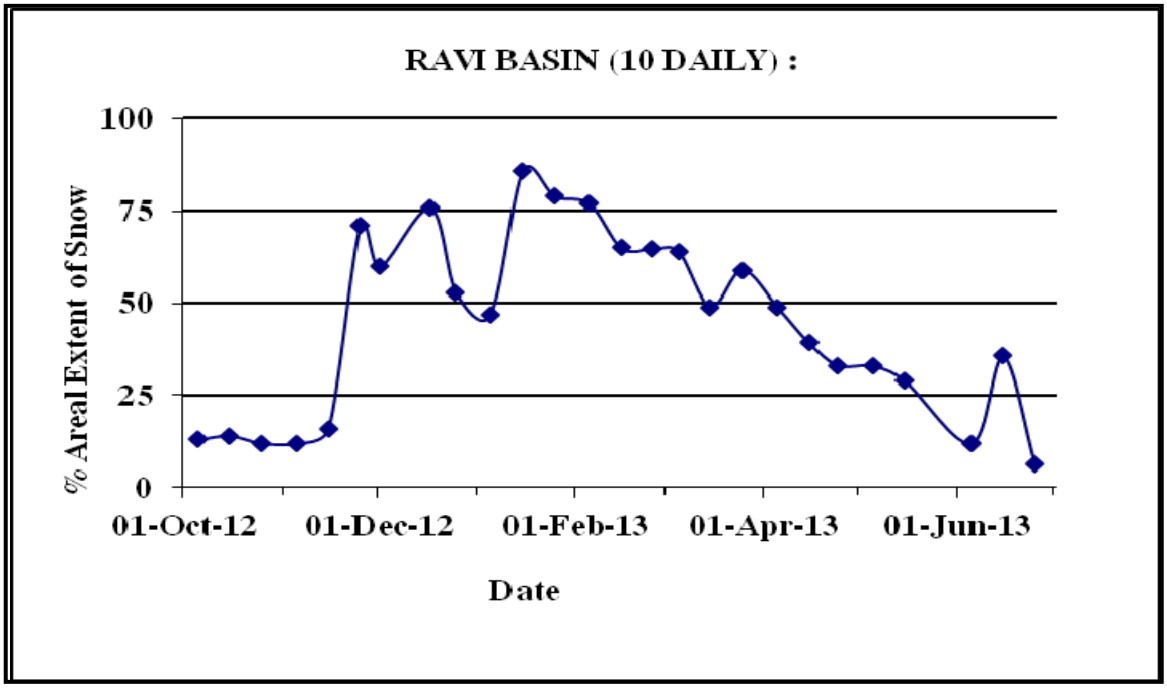
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	5-Oct-12	656	13	3	25-Oct-12	604	12
2	15-Oct-12	671	14				
November 2012							
4	5-Nov-12	598	12	6	25-Nov-12	3462	30
5	15-Nov-12	767	16				
December 2012							
7	5-Dec-12	2935	60	9	25-Dec-12	2576	53
8	15-Dec-12	3717	76				
January-2013							
10	5-Jan-13	2304	47	12	25-Jan-13	3869	79
11	15-Jan-13	4236	86				
February 2013							
13	5-Feb-13	3772	77	15	25-Feb-12	3179	65
14	15-Feb-13	3179	65				
March 2013							
16	5-Mar-13	3121	64	18	25-Mar-13	2893	69
17	15-Mar-13	2396	49				
April 2013							
19	5-Apr-13	2395	49	21	25-Apr-12	1626	33
20	15-Apr-13	1925	39				
May 2013							
22	5-May-13	1629	33	23	15-May-13	1402	29
June 2013							
24	5-Jun-13	569	12	26	25-June-13	315	6
25	15-June-13	1745	36				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: CHANDRA **BASIN AREA: 2433 Sq km**

S No	Date	Snow Cover (sq km)	Snow Cover (%)	S No	Date	Snow Cover (sq km)	Snow Cover (%)
October 2012							
1	2-Oct-12	1053	43	7	19-Oct-12	1364	56
2	4-Oct-12	1451	60	8	21-Oct-12	976	40
3	6-Oct-12	1094	45	9	24-Oct-12	2167	89
4	7-Oct-12	1009	41	10	26-Oct-12	1553	64
5	9-Oct-12(C)	1287	53	11	30-Oct-12	1339	55
6	14-Oct-12	1205	50	12	31-Oct-12	1218	50
November 2012							
13	4-Nov-12	1139	47	17	12-Nov-12	1316	54
14	5-Nov-12	1022	42	18	16-Nov-12	1272	52
15	7-Nov-12	1366	56	19	17-Nov-12	1125	46
16	11-Nov-12	1316	54	20	26-Nov-12	1957	80
December 2012							
21	1-Dec-12	2425	100	23	25-Dec-12	2431	100
22	17-Dec-12	2439	100	24	30-Dec-12	2432	100
January 2013							
25	3-Jan-13	2428	100	30	13-Jan-13	2429	100
26	6-Jan-13	2397	99	31	20-Jan-13	2433	100
27	8-Jan-13	2422	100	32	22-Jan-13	2441	100
28	10-Jan-13	2364	97	33	25-Jan-13	2433	100
29	11-Jan-13(C)	2264	93	34	30-Jan-13	2440	100
February 2013							
35	1-Feb-13	2440	100	38	18-Feb-13	2441	100
36	8-Feb-13	2439	100	39	20-Feb-13	2442	100
37	9-Feb-13	2435	100	40	25-Feb-13	2440	100
March 2013							
41	2-Mar-13	2438	100	44	17-Mar-13	2437	100
42	5-Mar-13	2435	100	45	21-Mar-13	2440	100
43	7-Mar-13	2441	100	46	26-Mar-13	2439	100
April 2013							
47	4-Apr-13	2440	100	50	19-Apr-13	2413	99
48	5-Apr-13	2438	100	51	24-Apr-13	2371	97
49	12-Apr-13	2440	100				

S No	Date	Snow Cover (sq km)	Snow Cover (%)	S No	Date	Snow Cover (sq km)	Snow Cover (%)
May 2013							
53	3-May-13	2350	97	56	15-May-13	2201	90
54	4-May-13(C)	2264	93	57	16-May-13	2161	89
55	8-May-13	2316	95	58	20-May-13	2104	86
June 2013							
59	6-Jun-13	1704	70	61	11-Jun-13(C)	1920	79
60	8-Jun-13	1629	67	62	21-Jun-13	1615	66

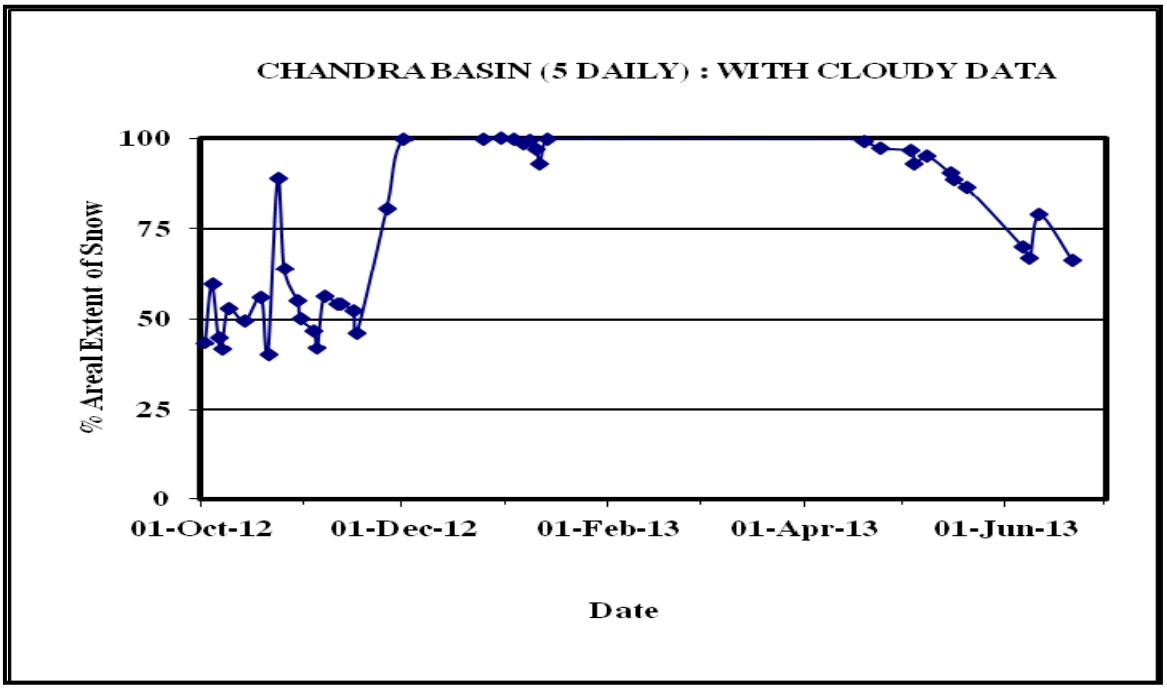
C= Cloudy Data

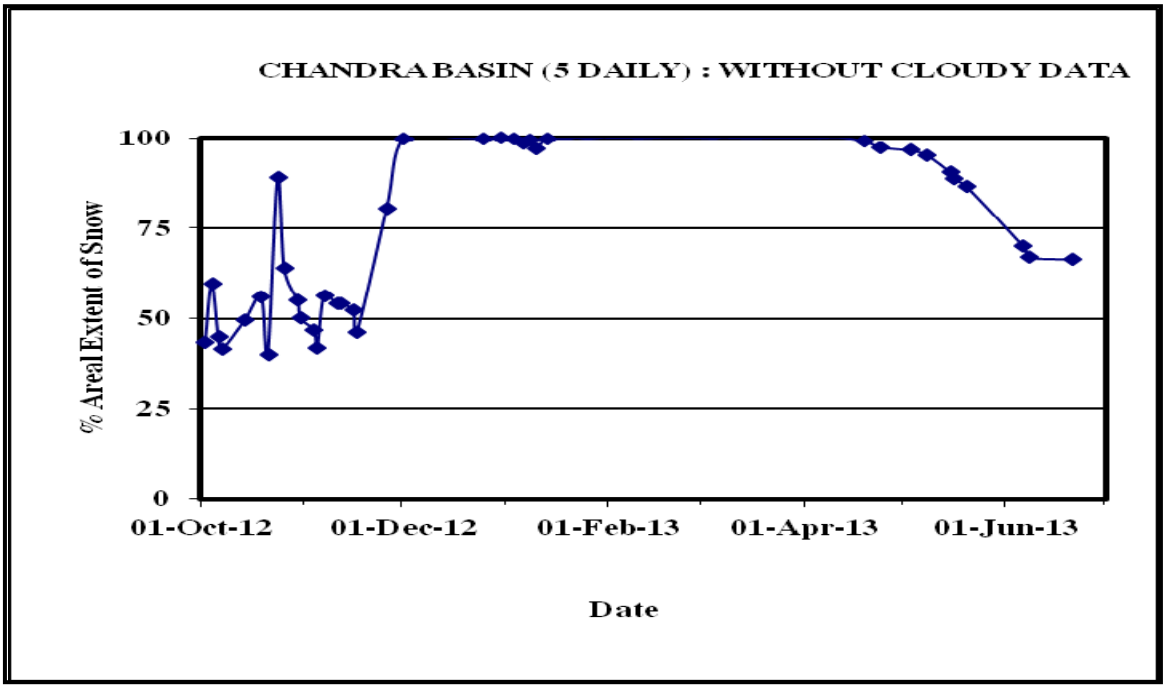
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: CHANDRA **BASIN AREA: 2433 Sq km**

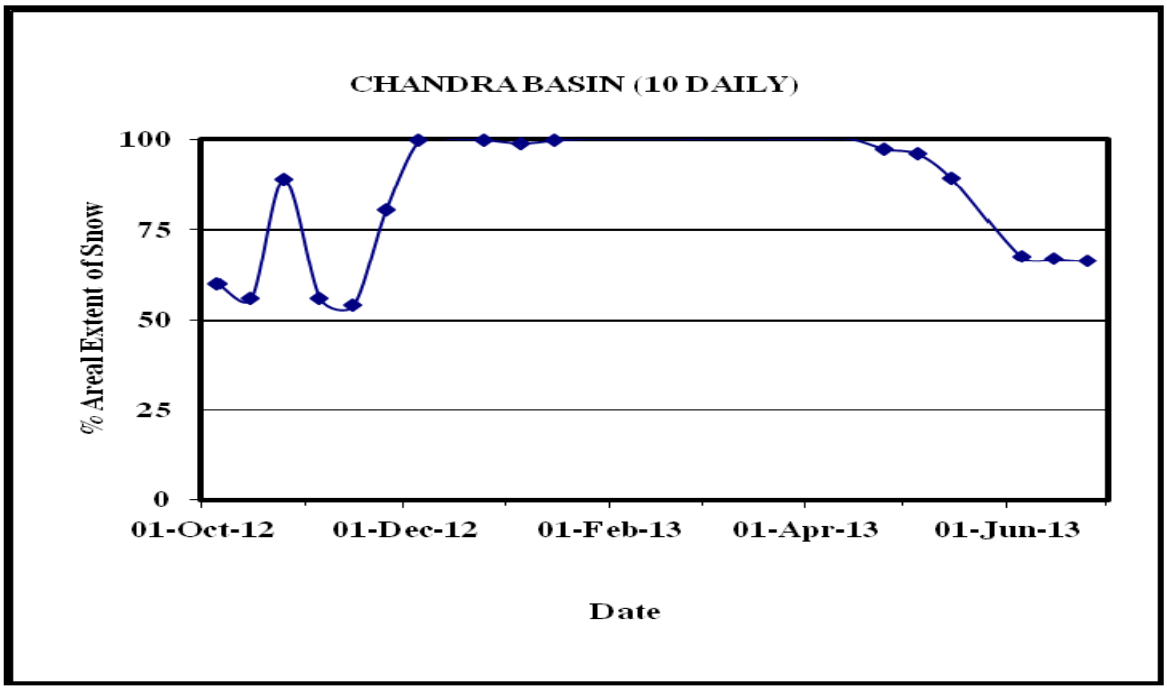
S No	Date	Snow Cover (sq km)	Snow Cover (%)	S No	Date	Snow Cover (sq km)	Snow Cover (%)
October 2011							
1	3-Oct-11	750	31	3	25-Oct-11	1880	59
2	15-Oct-11	1144	38				
November 2011							
4	5-Nov-11	1137	48	6	25-Nov-11	820	43
5	15-Nov-11	1953	80				
December 2011							
7	2-Dec-11	1094	45	9	25-Dec-11	2348	97
8	15-Dec-11	2353	97				
January 2012							
10	14-Jan-12	2442	100	11	25-Jan-12	2441	100
February 2012							
12	5-Feb-12	2441	100	14	26-Feb-12	2442	100
13	17-Feb-12	2442	100				
March 2012							
15	2-Mar-12	2442	100	16	25-Mar-12	2441	100
April 2012							
17	5-Apr-12	2411	99	19	24-Apr-12	2354	97
18	15-Apr-12	2441	100				
May-2012							
20	5-May-12	2333	96	22	25-May-12	2105	87
21	15-May-12	2281	94				
June 2012							
23	5-June-12	2097	86	25	25-June-12	1546	64
24	15-June12	1794	74				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



BHAGA BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: BHAGA **BASIN AREA: 1680 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	2-Oct-12	834	50	7	21-Oct-12(C)	687	41
2	4-Oct-12	922	55	8	24-Oct-12	1407	84
3	6-Oct-12	792	47	9	26-Oct-12	1043	62
4	7-Oct-12	751	45	10	30-Oct-12	896	53
5	14-Oct-12	935	56	11	31-Oct-12	843	50
6	19-Oct-12(C)	987	59				
November 2012							
12	4-Nov-12	784	47	15	12-Nov-12	838	50
13	7-Nov-12	891	53	16	16-Nov-12	937	56
14	11-Nov-12	871	52	17	17-Nov-12	825	49
December 2012							
18	1-Dec-12	1622	97	20	25-Dec-12	1654	98
19	17-Dec-12	1672	100	21	30-Dec-12	1686	100
January 2013							
22	3-Jan-13	1655	99	27	13-Jan-13	1655	99
23	6-Jan-13	1602	95	28	20-Jan-13	1602	95
24	8-Jan-13	1640	98	29	25-Jan-13	1640	98
25	10-Jan-13	1594	95	30	30-Jan-13	1594	95
26	11-Jan-13(C)	1510	90				
February 2013							
31	1-Feb-13	1694	100	34	18-Feb-13	1696	100
32	8-Feb-13	1694	100	35	20-Feb-13	1696	100
33	9-Feb-13	1693	100	36	25-Feb-13	1695	100
March 2013							
37	2-Mar-13	1694	100	41	17-Mar-13	1691	100
38	4-Mar-13	1687	100	42	19-Mar-13	1688	100
39	5-Mar-13	1690	100	43	21-Mar-13	1683	100
40	7-Mar-13	1694	100	44	26-Mar-13	1696	100
April 2013							
45	4-Apr-13	1682	100	48	19-Apr-13	1640	98
46	5-Apr-13	1677	100	49	24-Apr-13	1575	94
47	12-Apr-13	1695	100				

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May-2013							
50	3-May-13	1552	92	53	15-May-13	1408	84
51	4-May-13(C)	1513	90	54	16-May-13	1415	84
52	8-May-13	1528	91	55	20-May-13	1316	78
June-2013							
56	6-Jun-13(C)	1088		59	18-Jun-13	1132	67
57	8-Jun-13	1101		60	21-Jun-13	1132	67
58	11-Jun-13(C)	1074					

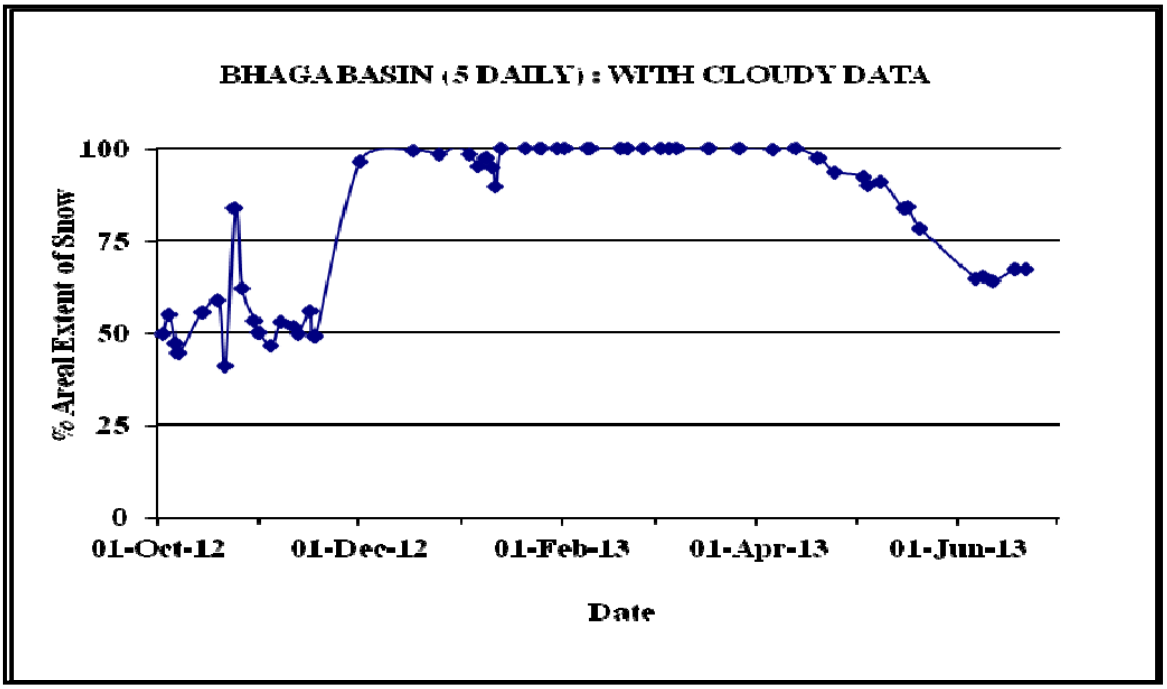
C = Cloudy data

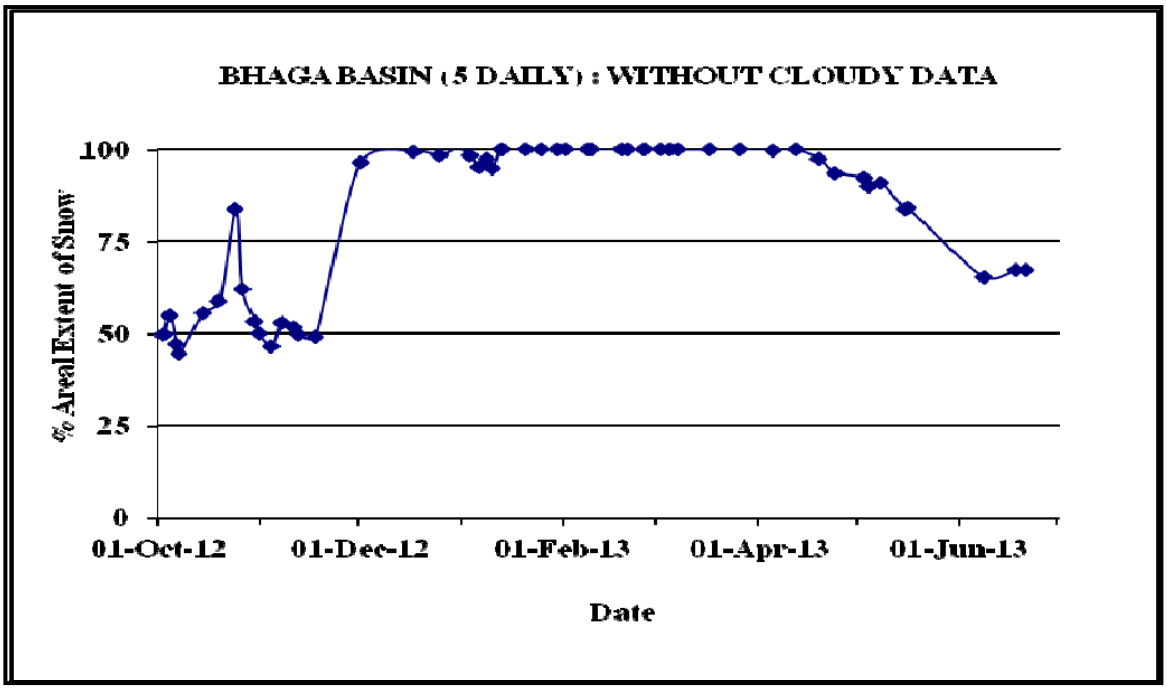
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: BHAGA **BASIN AREA: 1680 sq km**

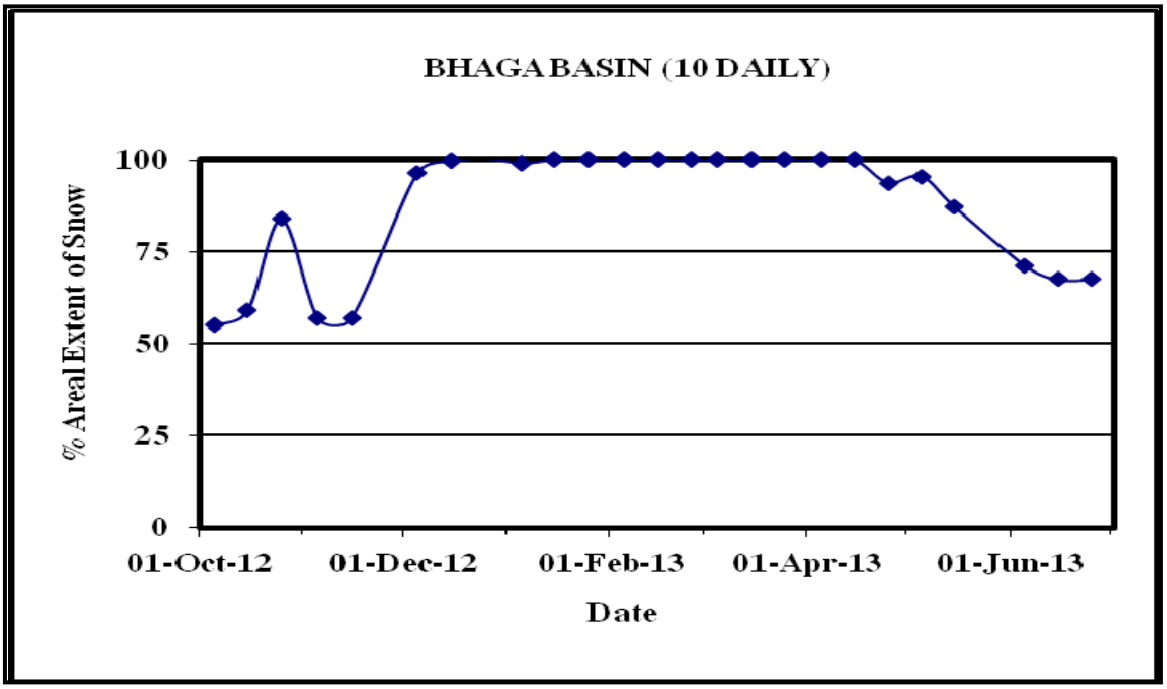
S No	Date	Snow cover (sq km)	Snow cover (%)	S. No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	5-Oct-12	922	55	3	25-Oct-12	1407	84
2	15-Oct-12	987	59				
November 2012							
4	5-Nov-12	891	53	5	15-Nov-12	872	52
December 2012							
6	5-Dec-12	1622	97	8	25-Dec-12	100	1680
7	15-Dec-12	1672	100				
January 2013							
9	5-Jan-13	1655	99	11	25-Jan-13	100	1680
10	15-Jan-13	1680	100				
February 2013							
12	5-Feb-13	1680	100	14	25-Feb-13	1680	100
13	15-Feb-13	1680	100				
March 2013							
15	5-Mar-13	1680	100	17	25-Mar-13	1680	100
16	15-Mar-13	1680	100				
April 2013							
18	5-Apr-13	1682	100	20	25-Apr-13	1575	94
19	15-Apr-13	1680	58				
May-2013							
21	5-May-13	1552	92	22	15-May-13	1408	84
June-2013							
23	5-June-13	1101	66	25	25-June-13	1132	67
24	15-June-13	1132	67				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



MIYAR BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: MIYAR **BASIN AREA: 4449 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	2-Oct-12	1200	27	7	19-Oct-12 (C)	2396	54
2	4-Oct-12 (C)	1739	39	8	21-Oct-12	1436	32
3	6-Oct-12	1207	27	9	26-Oct-12	1590	36
4	7-Oct-12	978	22	10	30-Oct-12	1606	36
5	9-Oct-12	1301	29	11	31-Oct-12	1336	30
6	14-Oct-12	1599	36				
November 2012							
12	4-Nov-12	1320	30	16	12-Nov-12	1369	31
13	6-Nov-12 (C)	1935	43	17	16-Nov-12	1529	34
14	7-Nov-12	1433	32	18	26-Nov-12	2082	47
15	11-Nov-12	1504	34	19	30-Nov-12	4405	99
December 2012							
20	1-Dec-12	4234	95	23	25-Dec-12	4040	91
21	12-Dec-12	3830	86	24	30-Dec-12	4152	93
22	17-Dec-12	4341	98				

January 2013							
25	3-Jan-13	3979	89	30	20-Jan-13	4433	100
26	5-Jan-13(C)	3534	79	31	22-Jan-13	4430	100
27	6-Jan-13	3711	83	32	23-Jan-13	3403	76
28	8-Jan-13	3943	89	33	25-Jan-13	4331	97
29	13-Jan-13	4343	98	34	30-Jan-13	4420	99
February 2013							
35	1-Feb-13	4301	97	38	18-Feb-13	4360	98
36	8-Feb-13	4433	100	39	20-Feb-13	4352	98
37	10-Feb-13	4421	99				
March 2013							
40	2-Mar-13	4400	99	44	21-Mar-13	3909	88
41	4-Mar-13	4340	98	45	24-Mar-13	3229	73
42	7-Mar-13	4229	95	46	26-Mar-13	4392	99
43	19-Mar-13	3995	90				
April 2013							
47	4-Apr-13	3982	90	50	12-Apr-13(C)	4421	99
48	5-Apr-13	3858	87	51	19-Apr-13	3588	81
49	11-Apr-13(C)	3163	71				

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
May 2013							
52	3-May-13	3284	74	55	15-May-13	2655	60
53	8-May-13(C)	2965	67	56	20-May-13	2004	45
54	10-May-13(C)	3646	82				
June-2013							
57	6-Jun-12 (C)	1419	32	59	11-Jun-13(C)	1859	42
58	8-Jun-13	1805	41	60	22-Jun-13	1527	34

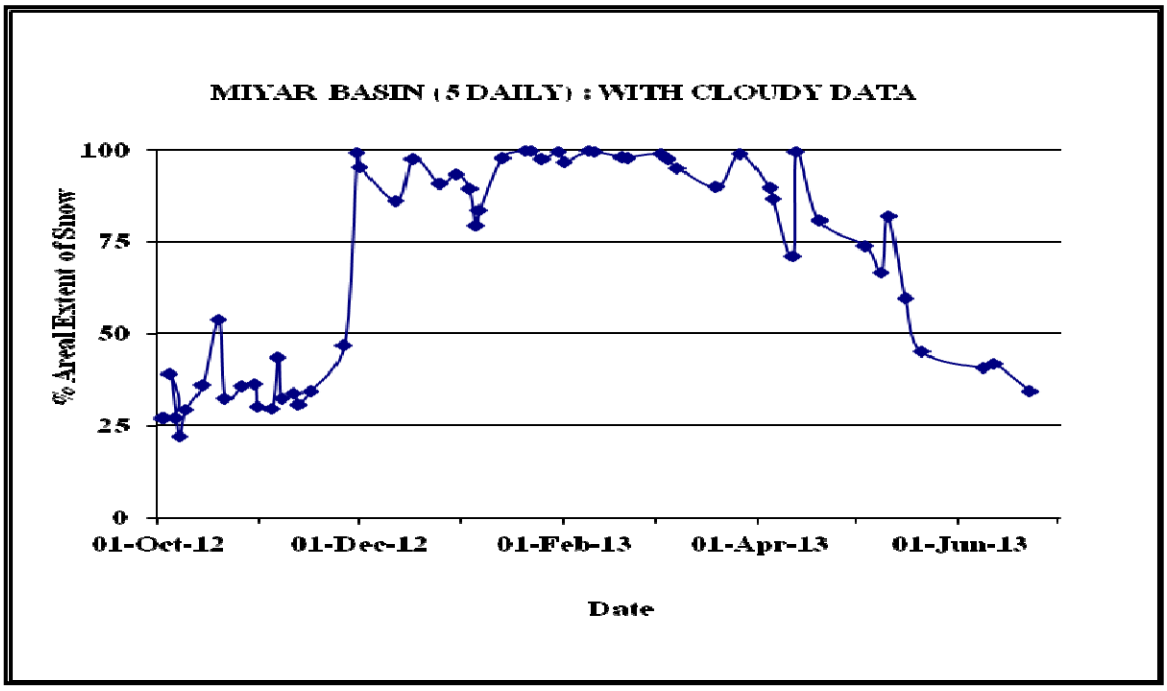
C = Cloudy Data

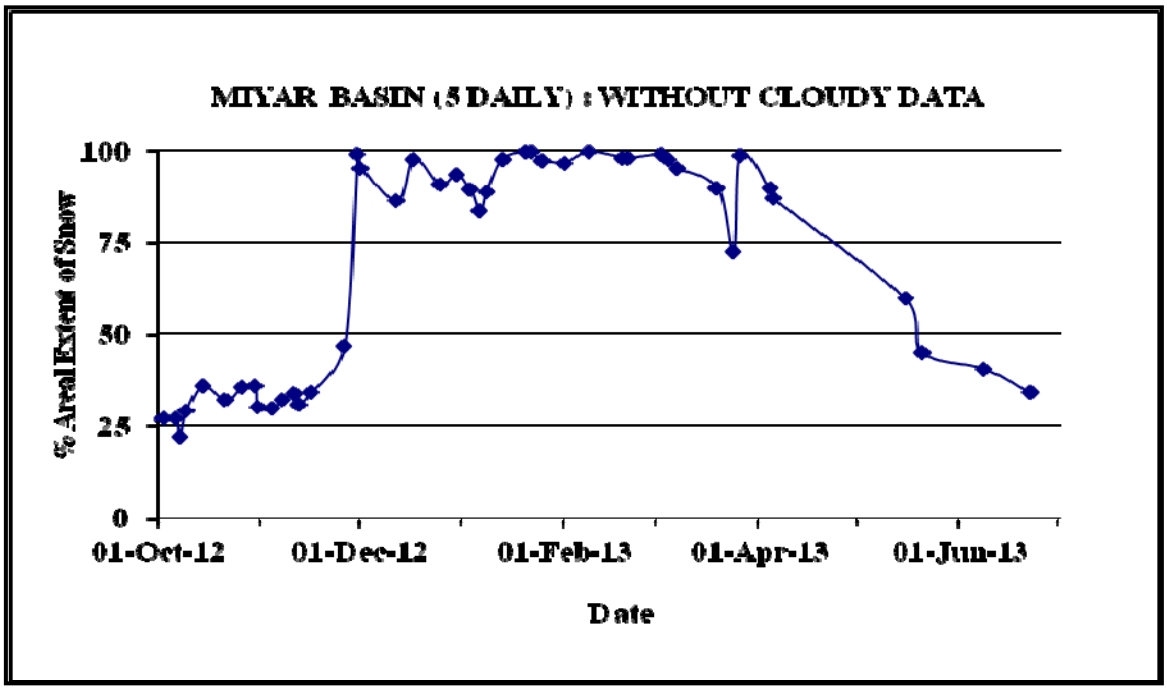
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: MIYAR **BASIN AREA: 4449 sq km**

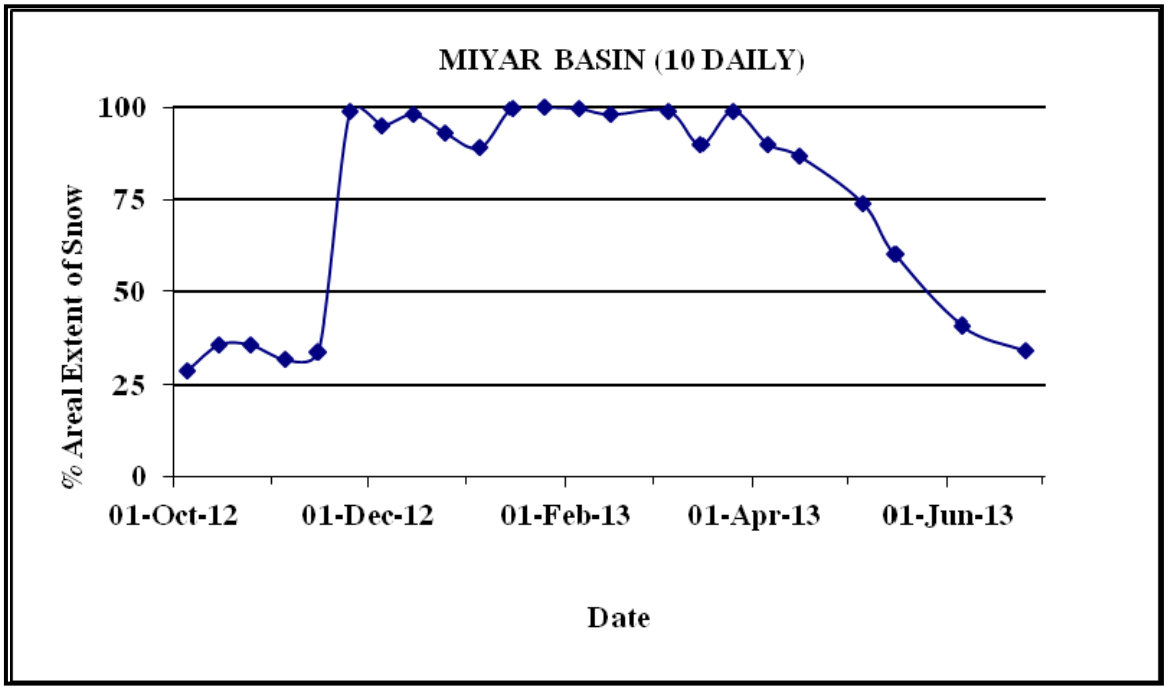
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	5-Oct-12	1149	29	3	25-Oct-12	1431	36
2	15-Oct-12	1138	36				
November 2012							
4	5-Nov-12	1306	32	6	25-Nov-12	4330	99
5	15-Nov-12	1244	34				
December 2012							
7	5-Dec-12	4224	95	9	25-Dec-12	4015	93
8	15-Dec-12	3942	98				
January 2013							
10	5-Jan-13	3695	89	12	25-Jan-13	4228	100
11	15-Jan-13	4432	100				
February 2013							
13	5-Feb-13	4428	100	14	15-Feb-13	4333	98
March 2013							
15	5-Mar-13	4344	99	17	25-Mar-13	4333	97
16	15-Mar-13	3970	99				
April-2013							
18	5-Apr-13	3872	87	19	15-Apr-13	3858	87
May-2013							
20	5-May-13	3195	74	21	15-May-13	2533	60
June-2013							
22	5-Jun-13	1665	41				
23	25-Jun-13	1527	34				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



BHUT BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: BHUT **BASIN AREA: 2218 Sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	2-Oct-12	643	29	6	21-Oct-12	833	38
2	6-Oct-12	618	28	7	26-Oct-12	795	36
3	9-Oct-12	706	32	8	28-Oct-12	975	44
4	14-Oct-12	848	38	9	30-Oct-12	813	37
5	18-Oct-12	1039	47	10	31-Oct-12	716	32
November 2012							
11	4-Nov-12	702	32	16	13-Nov-12	817	37
12	6-Nov-12(C)	1157	52	17	16-Nov-12	767	35
13	7-Nov-12	853	38	18	26-Nov-12 (C)	1040	47
14	11-Nov-12	815	37	19	30-Nov-12	2018	91
15	12-Nov-12	755	34				
December 2012							
20	1-Dec-12	1874	84	23	25-Dec-12	1857	84
21	12-Dec-12(C)	1742	79	24	30-Dec-12	1887	85
22	17-Dec-12	1990	90				
January 2013							
25	3-Jan-13	1797	81	31	20-Jan-13	2145	97
26	6-Jan-13	1654	75	32	22-Jan-13	2094	94
27	8-Jan-13	1777	79	33	25-Jan-13	1913	86
28	10-Jan-13	1757	43	34	30-Jan-13(C)	1975	89
29	11-Jan-13(C)	1488	67				
30	13-Jan-13	1896	85				
February 2013							
35	1-Feb-13	1858	84	38	18-Feb-13	1920	87
36	8-Feb-13	2062	93	39	20-Feb-13	1932	87
37	10-Feb-13	2008	91	40	25-Feb-13	2151	97
March 2013							
41	2-Mar-13	2054	93	45	19-Mar-13	1714	77
42	4-Mar-13	1928	87	46	21-Mar-13	1715	77
43	7-Mar-13	1853	84	47	26-Mar-13	1855	84
44	18-Mar-13	1769	80				

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
April 2013							
48	4-Apr-13	1798	81	52	19-Apr-13	1609	73
49	5-Apr-13	1714	77	53	23-Apr-13	1557	70
50	11-Apr-13	1070	48	54	24-Apr-13	1551	70
51	12-Apr-13	1975	89				
May 2013							
55	3-May-13	1551	68	58	15-May-13	1315	59
56	8-May-13(C)	1518	57	59	20-May-13	1059	48
57	10-May-13(C)	1275	82				
June 2013							
60	6-Jun-13(C)	827	37	62	11-Jun-13	751	34
61	8-Jun-13	959	43	63	22-Jun-13	801	36

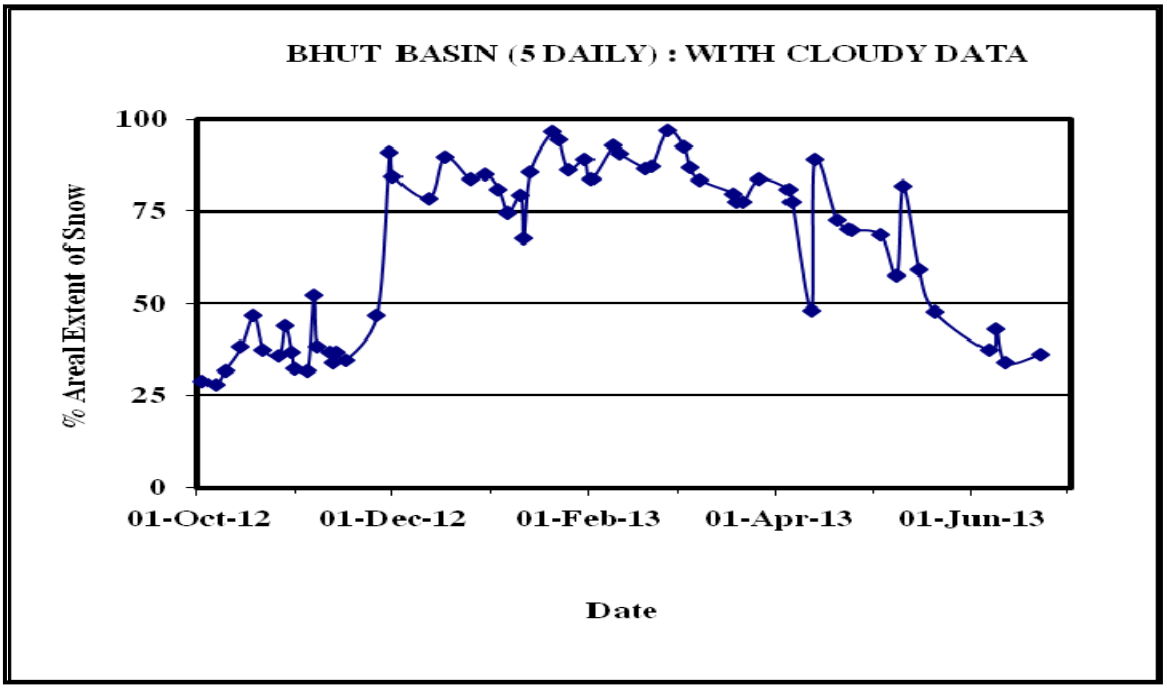
C = Cloudy Data

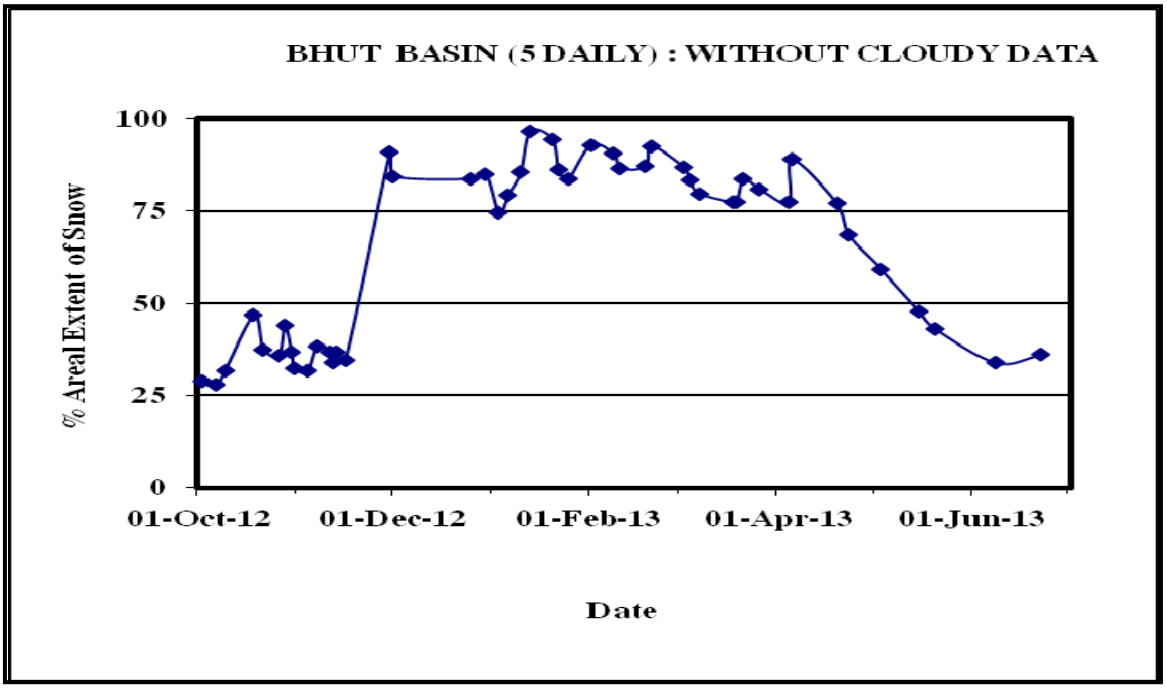
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: BHUT **BASIN AREA: 2218 Sq km**

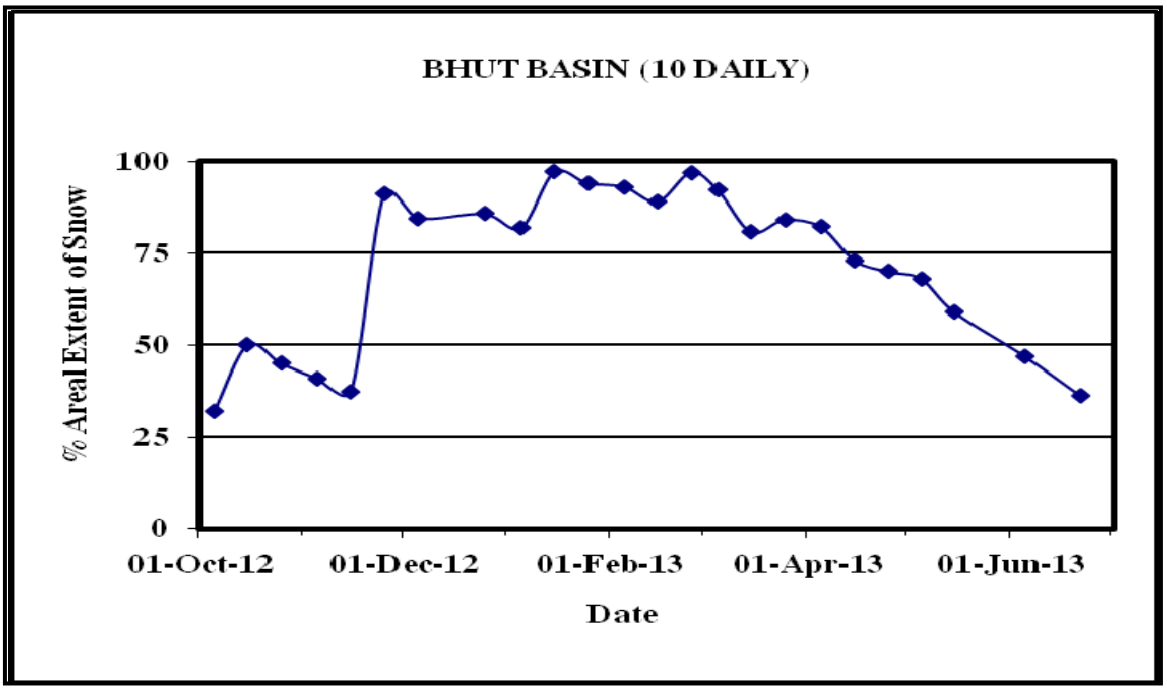
S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October-2012							
1	5-Oct-12	663	30	3	25-Oct-12	998	45
2	15-Oct-12	1109	50				
November 2012							
4	5-Nov-12	908	41	6	25-Nov-12	2017	91
5	15-Nov-12	828	37				
December 2012							
7	1-Dec-12	1874	84	9	25-Dec-12	1900	86
8	15-Dec-12	2086	94				
January 2013							
10	5-Jan-13	1817	82	12	25-Jan-13	1885	85
11	15-Jan-13	2030	92				
February 2013							
13	5-Feb-13	2029	91	15	25-Feb-13	1939	87
14	15-Feb-13	1974	89				
March 2013							
16	5-Mar-13	2044	92	18	25-Mar-13	1786	81
17	15-Mar-13	1790	81				
April-2013							
19	5-Apr-13	1821	82	21	25-Apr-13	1684	76
20	15-Apr-13	1939	87				
May-2013							
22	3-May-13	1581	71	23	15-May-13	1350	61
June-2013							
24	5-Jun-13	1043	47	26	22-June-13	801	36
25	11-June-13	751	34				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE



WARWAN BASIN

AREAL EXTENT OF SNOW (5 DAILY)

BASIN NAME: WARWAN **BASIN AREA: 4670 sq km**

S No	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
October 2012							
1	2-Oct-12	1099	24	6	14-Oct-12	1378	30
2	4-Oct-12(C)	1934	41	7	18-Oct-12	2736	59
3	6-Oct-12	1107	24	8	26-Oct-12	1741	37
4	8-Oct-12	1274	27	9	30-Oct-12	1708	37
5	9-Oct-12	1210	26				
November 2012							
10	1-Nov-12	1885	40	15	16-Nov-12	1670	36
11	4-Nov-12	1478	32	16	25-Nov-12	3338	71
12	6-Nov-12	1839	39	17	26-Nov-12(C)	2845	61
13	7-Nov-12	1651	35	18	30-Nov-12	4360	93
14	11-Nov-12	1654	35				
December 2012							
19	3-Dec-12	3664	78	23	25-Dec-12	4112	88
20	12-Dec-12	3925	84	24	28-Dec-12	2074	44
21	17-Dec-12	4529	97	25	31-Dec-12	4136	89
22	19-Dec-12	4513	97				

January 2013							
26	3-Jan-13	4058	87	31	20-Jan-13	4539	97
27	6-Jan-13	3661	78	32	22-Jan-13	4514	97
28	8-Jan-13	3990	85	33	25-Jan-13	4247	91
29	10-Jan-13	3839	82	34	30-Jan-13(C)	4321	93
30	13-Jan-13	4137	89				
February 2013							
35	1-Feb-13	4195	90	38	18-Feb-13	4194	90
36	8-Feb-13	4425	95	39	20-Feb-13	4175	89
37	10-Feb-13	4260	91				
March 2013							
40	2-Mar-13	4455	95	44	19-Mar-13	3857	83
41	4-Mar-13	4336	93	45	21-Mar-13(C)	3631	78
42	7-Mar-13	4086	87	46	26-Mar-13	3998	86
43	18-Mar-13	3974	85				

S NO	Date	Snow cover (sq km)	Snow cover (%)	S No	Date	Snow cover (sq km)	Snow cover (%)
April-2013							
47	4-Apr-13	3921	84	51	19-Apr-13	3422	73
48	6-Apr-13	3726	80	52	23-Apr-13(C)	3821	82
49	11-Apr-13(C)	3245	69	53	24-Apr-13	3182	68
50	18-Apr-13	3642	78				
May 2013							
54	3-May-13	3258	70	57	15-May-13	2885	62
55	8-May-13	2471	53	58	20-May-13	2034	44
56	10-May-13	3227	69	59	24-May-13	2434	52
June 2013							
60	6-Jun-13	1372	29	62	11-Jun-13	1425	31
61	8-Jun-13	1850	40	63	22-Jun-13	1385	30

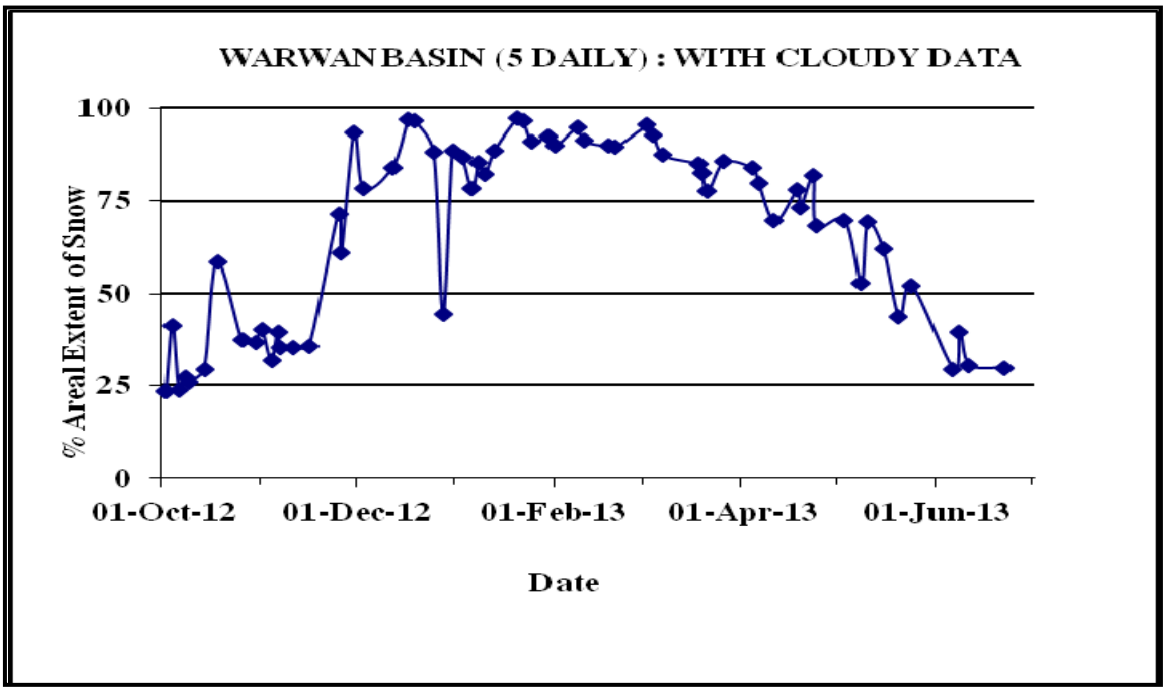
C = Cloudy Data

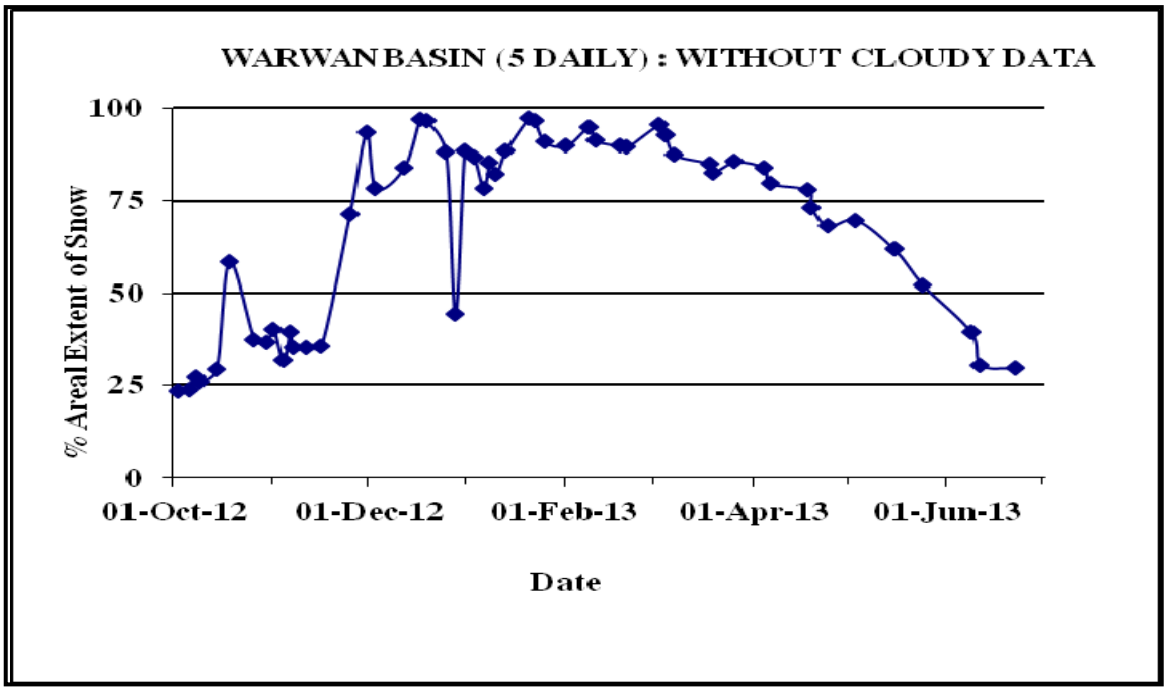
AREAL EXTENT OF SNOW (10 DAILY)

BASIN NAME: WARWAN **BASIN AREA: 4670 sq km**

S No	Date	Snow cover (sq.km)	Snow cover (%)	S No	Date	Snow cover (sq.km)	Snow cover (%)
October 2012							
1	5-Oct-12	1261	23	3	25-Oct-12	35	1728
2	15-Oct-12	2755	54				
November 2012							
4	5-Nov-12	1868	33	6	25-Nov-12	4343	66
5	15-Nov-12	1681	30				
December 2012							
7	5-Dec-12	3664	78	9	25-Dec-12	4156	52
8	15-Dec-12	4530	93				
January 2013							
10	5-Jan-13	4063	81	12	25-Jan-13	4530	91
11	15-Jan-13	4530	96				
February 2013							
13	5-Feb-13	4437	93	14	15-Feb-13	4203	87
March 2013							
15	5-Mar-13	4437	86	17	25-Mar-13	4016	82
16	15-Mar-13	3970	82				
April 2013							
18	5-Apr-13	3923	80	20	25-Apr-13	3043.17	65
19	15-Apr-13	3643	76				
May 2013							
21	5-May-13	3269	70	23	25-May-12	2434	52
22	15-May-13	2895	62				
June 2013							
24	5-June-13	1868	40	26	22-Jun-12	1385	30
25	11-June-13	1425	31				

SNOW COVER DEPLETION CURVE





SNOW COVER DEPLETION CURVE